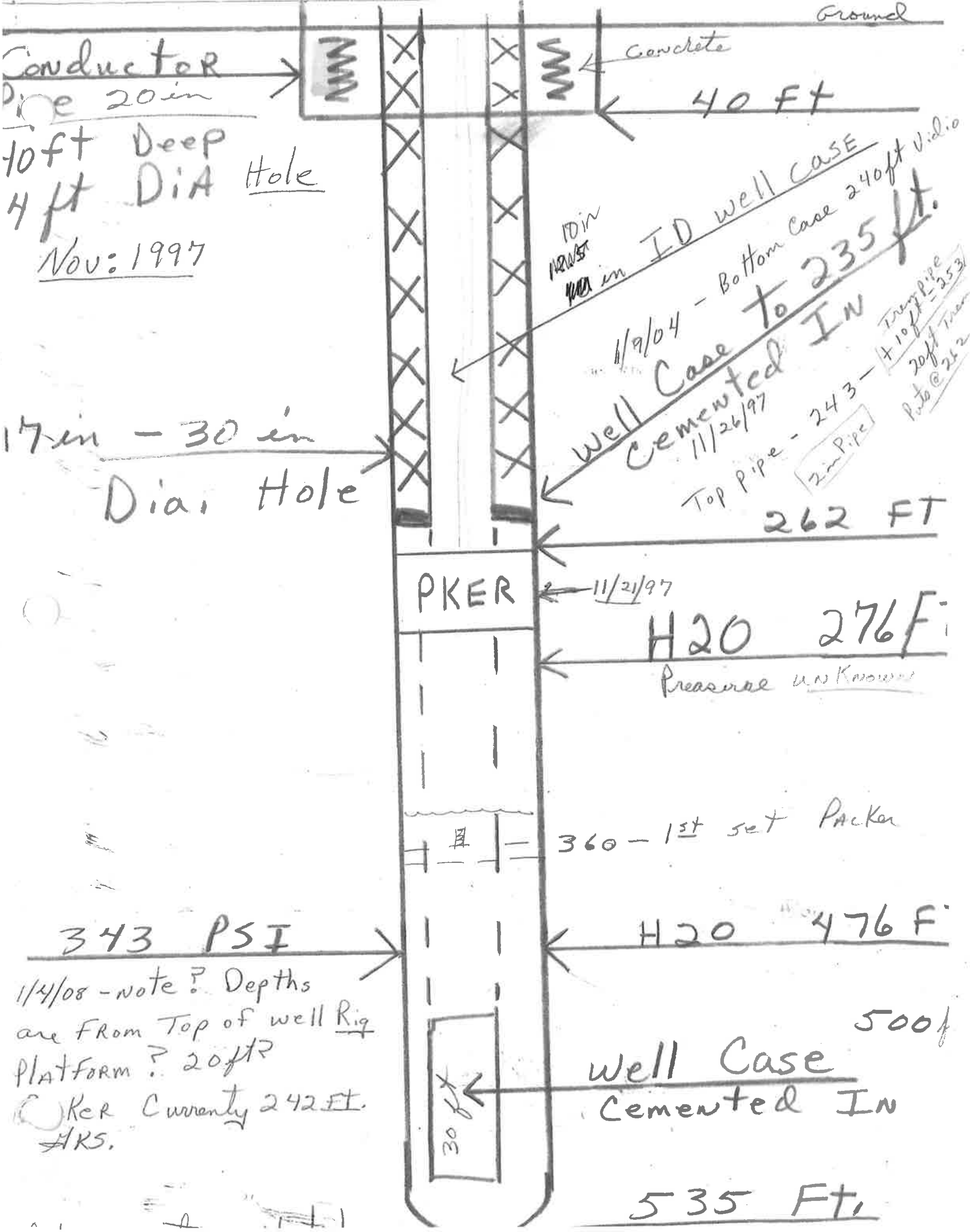
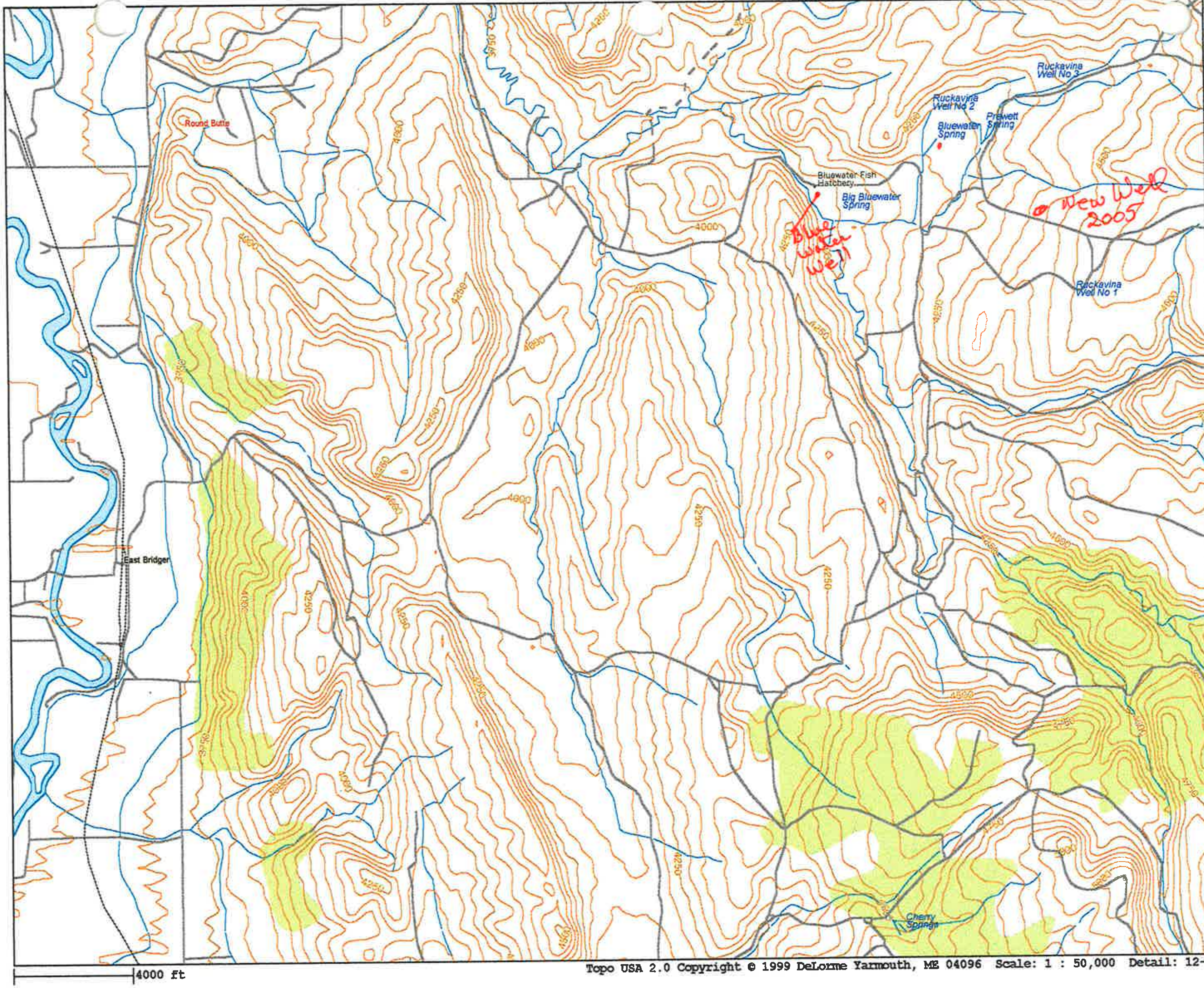

Ground
Conductor Pipe 20 in
40 ft Deep
4 ft DiA Hole
Nov: 1997
Concrete
40 Ft
10 in ID well CASE
1/9/04 - Bottom Case 240 ft Vidio
Well Case to 235 ft.
Cemented IN
11/26/97
Top Pipe - 243 - +10 ft = 253 Tremi Pipe
20 ft Tren Pipe @ 262
2 in Pipe
17 in - 30 in Dia Hole
262 FT
PKER
11/21/97
H20 276 Ft
Pressure unknown
360 - 1st set Packer
343 PSI
H20 476 Ft
1/4/08 - note? Depths are From Top of well Rig Platform? 20 ft?
Ker Currently 242 Ft.
HRS.
500 ft
Well Case Cemented IN
30 ft
535 Ft.

BLUEWATER WELL HISTORY

North ↑ Blue Water Hatcher MDFWP

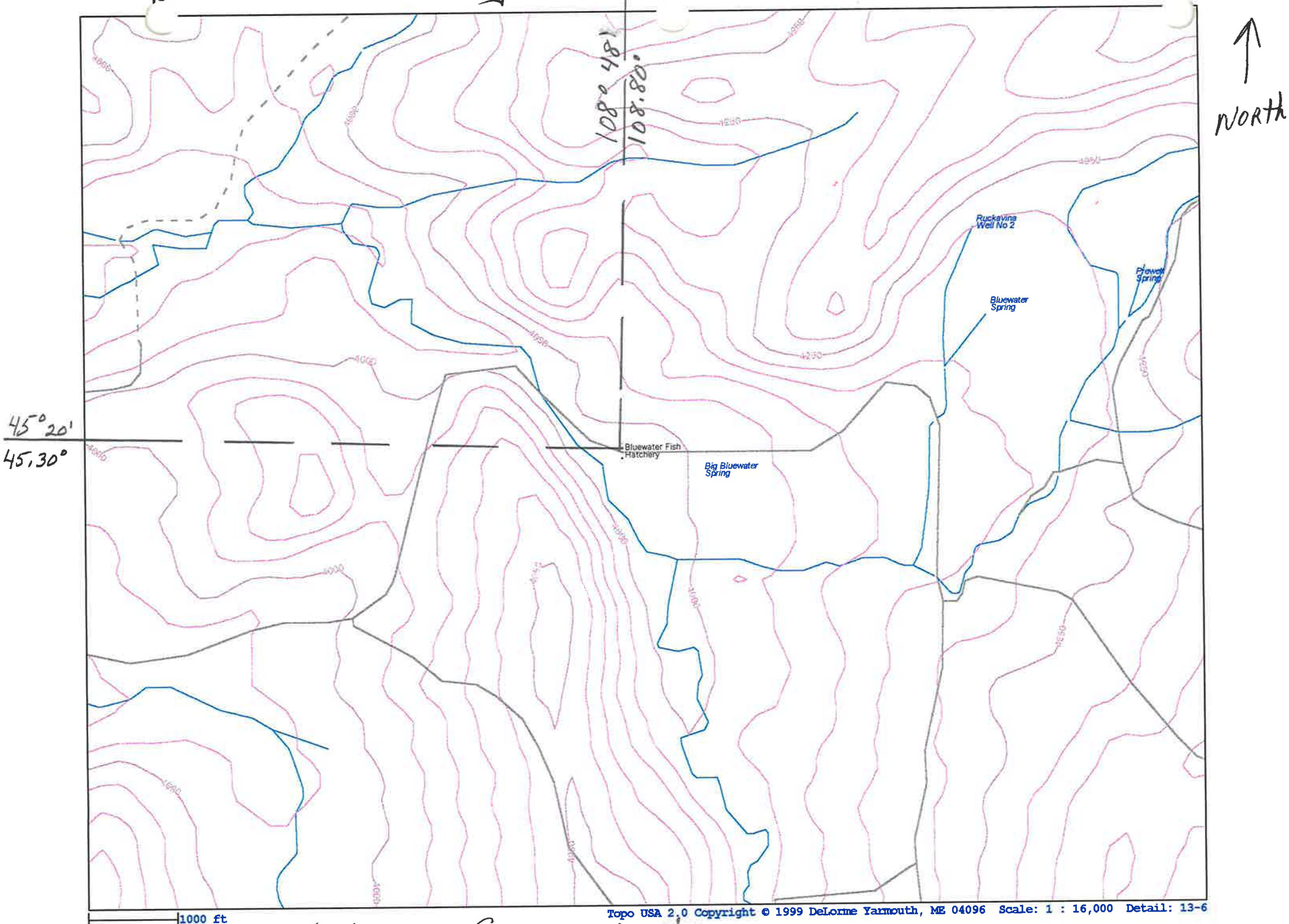
RK2 Plugged 8/06

New Well Drilled To replace



Topo USA 2.0 Copyright © 1999 DeLorme Yarmouth, ME 04096 Scale: 1 : 50,000 Detail: 12-0

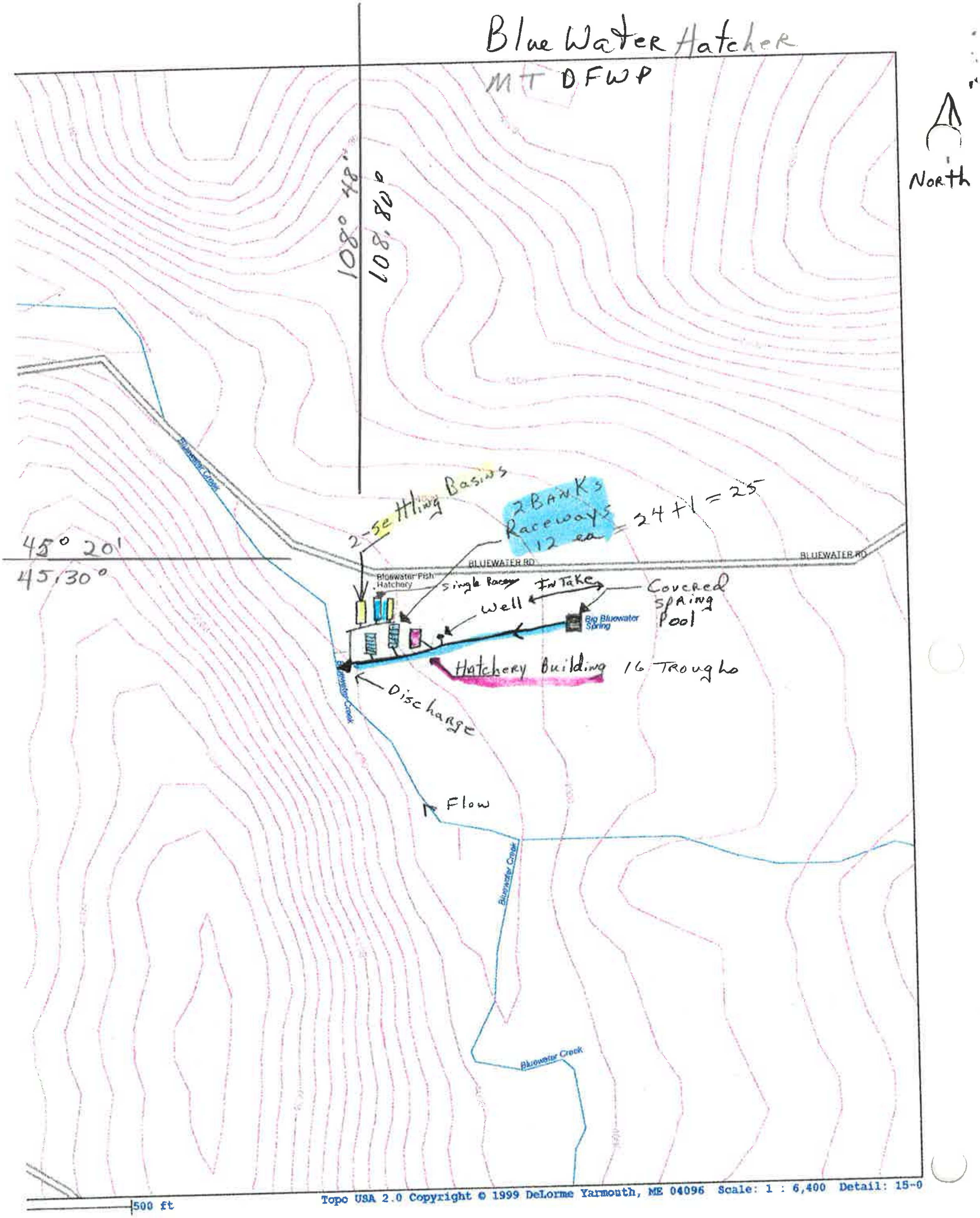
Blue Water Hatchery MDFWP T6S- R24- Sec 9



Cabron Co - Montana

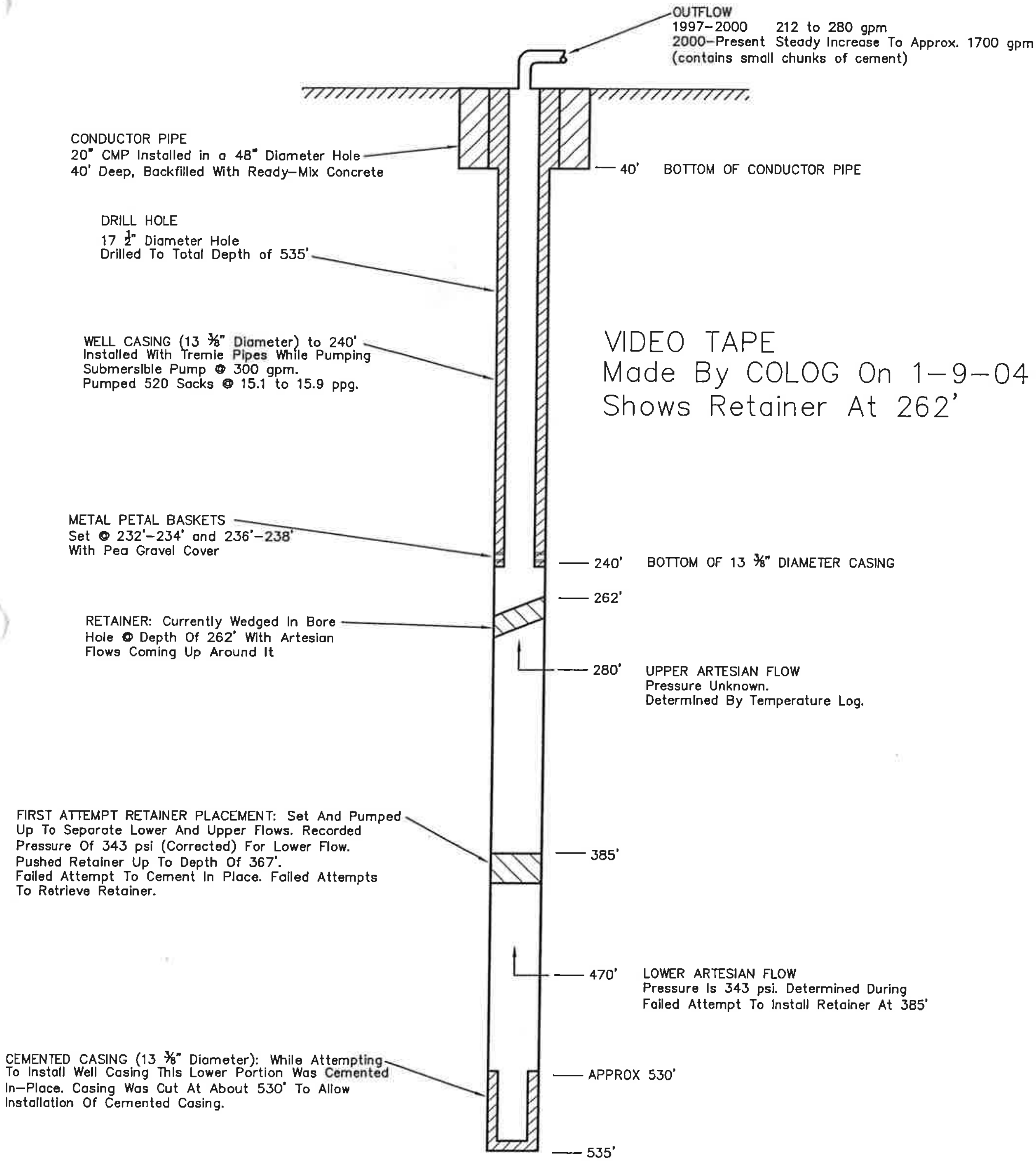
Blue Water Hatcher

MT DFWP



Carbon Co - Montana T6S : R24E : Sec 9

APPENDIX 1



June 2006 DATE PROJECT NO. well.dwg FILE NO.	SHEET TITLE **EXISTING BLUEWATER WELL CONDITIONS**	PROJECT TITLE **BLUEWATER TROUT HATCHERY**	INFORMATION PROVIDED BY GREG STAFFILENO, S.K. GEOTECHNICAL AND GARY SHAVER, MONTANA FISH, WILDLIFE AND PARKS

Chronological Flow History Table

Bluewater Springs Trout Hatchery
P. O. Box 423
Bridger, Montana 59014

Date	Comments	Bluewater and Small Spring Combined GPM	Bluewater Spring Flow ONLY	Well Flow ONLY	Well Head PSI	Bluewater Spring and Well Flow Combined	Estimated Spring Flow Minus Well From Spring Flow
Dec-77	USGS	4300					
May-85	MT DNRC	4245					
Oct-87	Gary Shaver	3933					
Oct-89		3645					
Aug-91		3491	2991				
Nov-91		3622	2890				
10/29/1997			2836				
11/7/1997			2968				
12/3/1997	Well Drilled 11/97			212			
2/25/1999		4003	3319				
May-99		4133					
Mar-00		4053					
Apr-00			3055				
Dec-01				488		2992	2504
Jul-02				659		3190	2531
Nov-02				750	8.5	3312	2562
Jan-03				787	9.0	3392	2605
6/23/2003	Split flows of well and spring		2667	935	10.0	3679	2744
7/15/2003				940	10.0	3357	2417
8/2/2003	Split flows of well and spring		2449	940	10.0	3392	2452
Oct-03				990	10.5		
1/8/2004				1034	10.8	3232	2198
1/9/2004			2343				0
1/10/2004			2326				0
2/18/2004				1049	10.8	3392	2343
3/1/2004				1048	10.8	3270	2222
4/7/2004	Well meter broken			N/A	12.3	3436	
12/15/2004				N/A	13.5		
2/23/2005			2152	1209	13.0	3392	
6/14/2005			2279	1275	13.7	3554	
9/26/2005			2218	1424	15.5	3642	
3/7/2006			2313	1675	18.0	3988	
4/5/2006			2413	1745	18.5	4158	

APPENDIX 3

Osborne McDevitt
EnviroScience LLC

Providing Environmental and
Hydrogeological Evaluation
and Management Services

December 8, 1997

Project No. BRMT:SC5

Mr. Gregory Staffileno, P.E.
Braun Intertec Corporation
2611 Gabel Road
Billings, MT 59102

Dear Greg:

Re: Preliminary Observations on Hydrogeologic Conditions, Bluewater Hatchery Well

As you requested, this letter addresses some preliminary observations of the hydrogeologic conditions and potential well yield, given the experience to date with the initial Bluewater Hatchery well. More than any other observation, in my view, the conditions experienced with the initial well demonstrate the difficulty of making reliable predictions of groundwater yield and quality in such a dynamic hydrogeologic setting which has little previous subsurface exploration. Please consider my comments in this light.

Hydrogeologic Setting

The initial well encountered a unique hydrogeologic setting due to its location on the crest of a major faulted anticline, which is the groundwater discharge point for regional aquifers recharged in the west Pryor Mountains. As discussed in the Hydrogeologic Evaluation report (Braun Intertec, 1997) the hatchery property is situated at a unique position due to the regional geologic structure, proximity to several faults and minimum rock overburden. The faults and associated fractures provide the avenues for spring water discharge, believed to be driven by high artesian pressures in the underlying Tensleep and Madison aquifers.

During drilling, the borehole encountered two artesian flows of groundwater, at depths of 280 and 470 feet below land surface (bls). According to the geologic log of Johnson, these zones are in the lower Piper formation (Jurassic age) and upper Chugwater formation (Triassic age), respectively. These formations are not normally aquifers. Based on the limited reports (principally Zimmerman, 1964) and data available prior to this project, significant quantities of pressurized groundwater were to be first expected in the lower Chugwater formation or Tensleep sandstone formation.

I remain of the belief that the source of the water flows encountered by the initial borehole is upward leakage from the Tensleep and Madison aquifers. The conditions encountered indicate that the hatchery area is faulted and fractured to a greater extent than elsewhere such that the confining beds overlying these aquifers are allowing extensive leakage from the source aquifers to the overlying siltstones and argillaceous limestones. The relatively low yield and high total dissolved solids (TDS) concentration of the two flows encountered by the borehole indicates that these formations are not likely the primary source aquifers of Big Bluewater Spring. However, it is likely that these formations contribute some water to the spring, which would explain the higher TDS of Big Bluewater Spring compared to the Ruckavina well.

Water quality data from the initial borehole indicating there is an inverted TDS profile (TDS decreasing with depth), support the theory that the water flows encountered were derived from deeper sources with low TDS. A water sample collected October 31, 1997 from the flowing borehole with both water flows contributing gave a TDS value of 4,550 mg/l. A sample taken on November 6 from the deeper flow (Braun Intertec, pers. comm.) gave a TDS of 3,490 mg/l.

Observations on Well Yield

In its initial Hydrogeologic Report, Braun Intertec (1996) estimated that, given the limited available information, the properties of the Madison aquifer supported a potential well yield of 2,000 to 3,000 gpm, but that due to the uncertainties of well-spring and well-well interferences, an estimate of 1,000 gpm per well was more reasonable to assume. The high pressure water flows encountered in the initial well suggest that this statement was realistic, and, if the source of the pressure is upward leakage from the Tensleep and Madison aquifers, perhaps conservative.

The measured shut-in pressure of the lower flow zone was reported to be 343 psi at a depth of 380 feet (Braun Intertec, pers. comm.). This gives an equivalent hydraulic head value of 792 feet, or about 412 feet above land surface at that site. With a flow (Q) of 175-200 gpm at land surface produced by 412 feet of drawdown (s), the specific capacity (Q/s) of the uncompleted Bluewater well was 0.42-0.49 gpm/ft. During the installation of the surface casing on November 30, the well was pumped at about 264 gpm with about 122.5 feet of drawdown. Subtracting the 175-200 gpm of natural artesian flow gives a specific capacity of about 0.52-0.73 gpm per foot.

By comparison, Zimmerman (1964) estimated that the specific capacity of the Ruckavina Well #2 was 26 gpm/ft, and Aquoneering, Inc. estimated the specific capacity of Big Bluewater Spring at 133 to 200 gpm/ft (Braun Intertec, 1996). It can be seen that the Bluewater well is producing water from lower permeability rocks. Whatever fault or fractures the well may have encountered, they apparently are not highly permeable. If they were, the ambient pressures would have produced very large flows.

Given the above analysis, I believe that the most likely scenario for the shallow high pressure water flows in the Bluewater well is that groundwater, under even higher pressure in the Tensleep and Madison formations, is forced upward along the faults and fractures, where it encounters and/or creates weaknesses along bedding planes, gypsum beds or unconformities in the overlying rocks, and moves laterally in zones such as was intersected during drilling at 280 and 470 feet.

If, as we suspect, groundwater is under very high pressure in the Tensleep and Madison aquifers, and if these aquifers have the permeability and storage potential typically found in other geologically similar areas, then we could expect wells drilled in the vicinity of the hatchery to produce relatively high yields, with minimum interference. Assuming wells could be properly designed and installed under such high pressure and risky conditions, the outlook for obtaining 2,000 gpm per well is good. This must be considered speculative, however, since we still do not have any scientific data on the target aquifers at this site.

Other Hydrogeologic Issues

Pressure gradient
It is noteworthy that the Bluewater well pressure measurement indicates that groundwater is held at pressures just slightly below the average rock fracture gradient (0.75 - 1 psi/ft) (B. Loyd, pers. comm.). If this condition persists with depth to the Madison aquifer, it is possible that a formation pressure of 1,000 psi or more could exist. Ordinarily this extremely high pressure to depth relationship would be unlikely. However, it is possible that karst conditions in the Madison formation, along with fault and fracture development, could transmit anomalous high pressures from the high portion of the Pryor Mountains.

Ruckavina Well #2 (RW2)
New, valuable information on deep formation pressures could possibly be obtained from RW2. This well has lost its integrity (Aquoneering, pers. comm) and continues to worsen, possibly contributing to the shallow, high pressure water problem. It is recommended that a well bore survey of this well be conducted by a wireline service company. If the lower reaches are accessible, a down-hole pressure reading may be taken. A the same time, the survey will show the condition of the well, and indicate whether it can be salvaged, or how to abandon it. The next step should be to properly repair or abandon RW2. In the process, flow and pressure tests will greatly aid any redesign of a new well, and provide needed hydrogeologic data to predict well yields and spacing.

The monitoring of the Ruckavina Well #2 (RW2) on the Raglan Ranch which has been performed by Braun Intertec and Aquoneering indicates that well has been loosing flow over the years, and that large amounts of water are escaping through a casing break at a depth of 241 feet (Aquoneering, pers. comm.). Other breaks in the casing at lower depths could be possible. A large spring (the "Breakout Spring") continues to flow at a rate exceeding 300 gpm in a hayfield southeast of RW2 which was reportedly caused when that well was shut-in. Aquoneering reports that as the well flow has declined in 1997, the flow from this spring has increased. The land surface at the Bluewater well is approximately 235 feet lower than at RW2, while the top of the Chugwater formation is about 360 feet lower.

We believe from the reported history of the Breakout Spring near RW2, that the failed well is contributing to localized increases in shallow water pressure. This situation is a concern for drilling at the Bluewater hatchery, but the extent of influence of this leakage is unknown. If there were an ideal hydrogeologic conduit, such as a highly permeable confined aquifer from RW2 to the Bluewater well in the Piper or upper Chugwater formation, it is possible that the deep formation pressure from RW2 could be transmitted to the Bluewater well.

However, this does not seem likely given our observations of these formations, and the fact that the Breakout Spring already relieves some pressure near the failed RW2. The higher elevation of the water flow out the RW2 break could generate up to 119 psi at the Bluewater well, but much of this would likely be lost to friction in the rocks over the roughly one mile distance. The only known "conduit" for pressure could be the fault which was mapped by Zimmerman (1964) and Braun Intertec (1996) which is in the vicinity of both wells. This potential connection could be investigated with surface and shallow subsurface geophysical methods, such as electrical resistivity, electromagnetic conductivity and soil thermometry.

Summary and Recommendations

Given the preliminary nature of the available information on the Bluewater well and the analysis above, it is my opinion that water pressures in the target aquifers (Tensleep and Madison), are likely greater than the 450 to 500 psi originally predicted on the basis of the information available before drilling. It is also possible that drilling anywhere on the hatchery property could encounter shallow high pressure water flows. Drilling of the rocks in this area results in zones of weakness which are exploited by the high pressure water and are very difficult to control with conventional technologies. The location of wells will require re-evaluation, since drilling at the hatchery may prove too expensive and risky, even with alternate well designs. Gaining surface elevation and moving out of the valley, away from the faults and existing springs would likely reduce the risk.

Based on the above discussion and available information, we recommend the following:

- Before considering any further drilling, the information gained from this first well should be carefully evaluated by specialists including geologists, hydrogeologists and drilling engineers, and additional information collected as required,

- New estimates of formation pressures should be made, based on results of the Bluewater well and, if possible, a wireline survey of Ruckavina #2,

- Re-evaluate the location of any new wells drilled for the hatchery, considering higher surface elevations, offset from faults, and locations off the current hatchery property,

- Investigate the potential hydraulic connection along the faults between the Bluewater hatchery area and Ruckavina #2, using surface and subsurface geophysical and hydrogeologic techniques.

If I can provide any further information or clarification of these matters, please contact me at (406) 655-9555.

Respectfully submitted,
Osborne McDevitt EnviroScience LLC

Thomas J. Osborne

Thomas J. Osborne, CGWP
Principal Hydrogeologist

Montana Department FW&P
Bluewater Springs Trout Hatchery
Water Well No. 1
SWNW Sec. 9-T6S-R23E
Carbon County, Montana

Spudded:	October 26, 1997 @ 9:45 PM
Completed 17½" Hole:	October 29, 1997 @ 10:30 PM
Elevation:	Ground 3975' KB 3987'
Total Depth:	535'

A water flow was encountered during drlling of the surface hole. Attempts to cement the surface casing and shut off the water flow were unsuccessful. Operations were temporarily suspended November 3, 1997 @ 8:00 AM while awaiting arrival of packers for abandonment.

Formation Tops

JURASSIC			
Swift	18?	+2969	
Rierdon	87	+2900	
Normal Fault	245		65' Missing
Piper	246	+2741	
Gypsum Springs	314	+2673	
TRIASSIC			
Chugwater	370	+2617	

Discussion:
The Rierdon to Chugwater interval in the water well is 283 feet thick as compared to 378 feet in the Eclipse Energy dry hole 3½ miles to the southeast (Sec. 23-T6S-R23E). Correlation of the Gamma Ray log from both holes suggests a normal fault may occur immediately above the Piper with displacement of about 65 feet. This fault is near the water zone and its fractures probably aided communication with an existing water zone.

Montana Dept. FW&P
Bluewater Springs Trout Hatchery
SWNW Sec. 9-T6S-R23E
Carbon County, Montana

SWIFT SANDSTONE 18? (+2969)

40- 60	Sandstone, very fine-fine grained, light grayish yellow, fair sorting, sub-angular, moderately calcareous to limey, few scattered dark gray accessory grains, micaceous, trace glauconite; streaks Limestone, crypto-crystalline, tan, dense, washed fossil fragments common; streaks Shale, reddish brown, very silty and sandy in part, calcareous; trace Anhydrite, white, earthy, dense.

RIERDN 87 (2900)

60- 80	Limestone, micro-cryptocrystalline, pale yellow, light gray-tan, cream, fragmental in part, argillaceous; streaks Siltstone-very fine grained Sandstone, brick red, argillaceous to shaley, dolomitic in part; trace Anhydrite, amorphous, white, earthy; influx LCM material.
80- 95	No sample - 99% LCM.
95-120	Limestone, crypto-microcrystalline, light gray to gray, gray-tan; grades to Marl, few streaks sandy, fragmental, few streaks of pellets in micrite matrix.
120-150	Shale, dull red, reddish brown, chunky, silty, calcareous; few streaks Limestone, as above, occasionally lavender, argillaceous, dense.
150-180	Limestone, micro-cryptocrystalline, gray-brown, dark brown, gray, argillaceous; Shale, as above.
180-210	Limestone, as above; streaks Shale, as above.
210-240	Limestone, as above.

PIPER LIMESTONE 246 (+2741)

240-270	Limestone, microcrystalline, gray, gray-tan, brown, fragmental in part, earthy in part, streaks pellets and interclast fragments in micrite cement.
270-300	Limestone, as above, streaks of pellets; slight increase in Shale, dull red, reddish brown, chunky.

GYPSUM SPRINGS 314 (+2673)

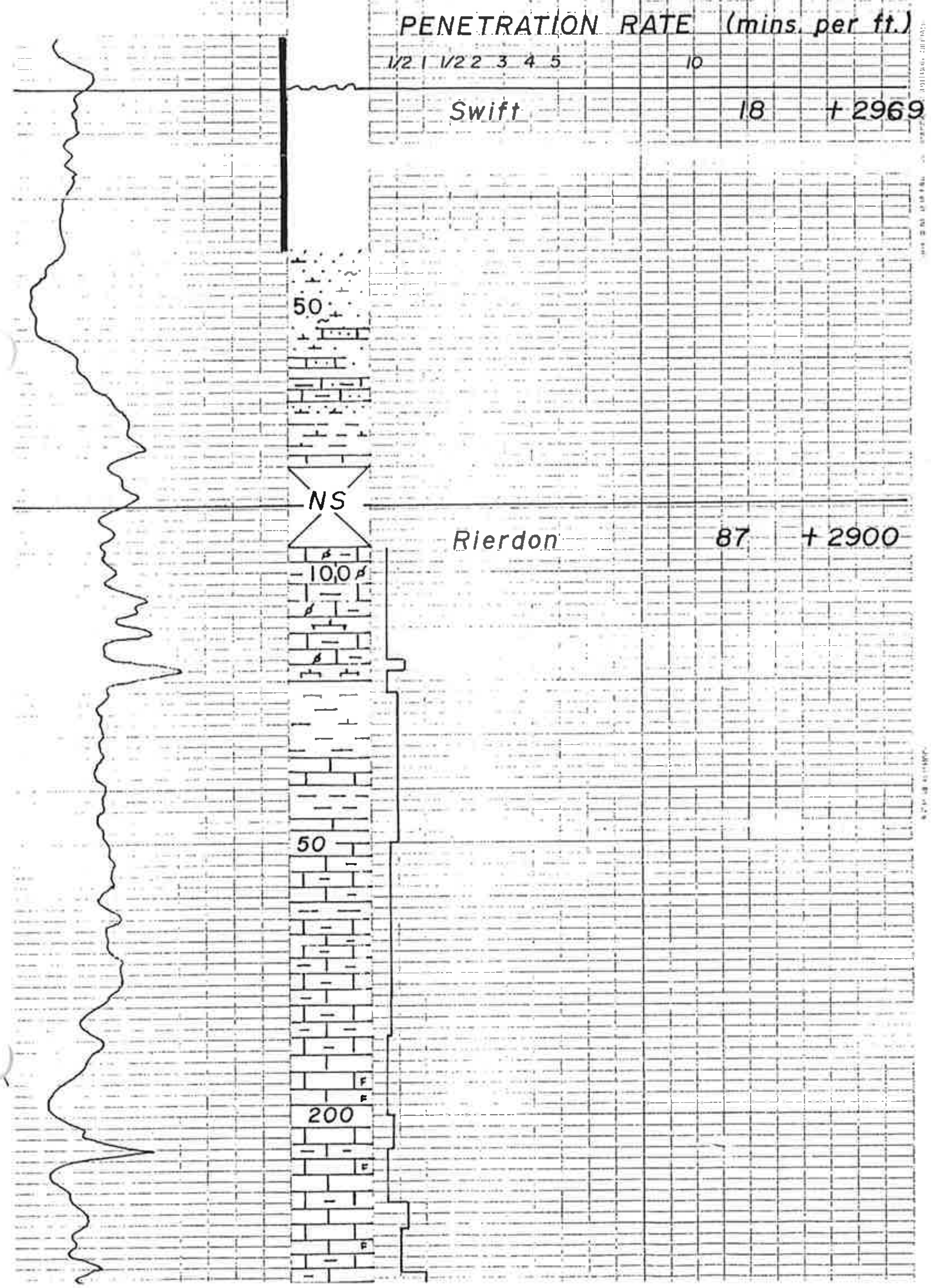
300-330	Shale, dull red, brick red, chunky, moderately calcareous in part; influx Anhydrite, crystalline, amorphous, white, earthy in part.
330-360	Shale, as above, rarely reddish orange, dolomitic; Anhydrite, as above.
	CHUGWATER 370 (+2617)
360-390	Siltstone, bright reddish orange, orange, very argillaceous; grades to silty Shale, few Anhydrite inclusions; trace Anhydrite, as above.
390-420	Siltstone, as above; streaks Anhydrite, amorphous, white, clear.
420-450	Siltstone, as above; grades to silty Shale, rarely dolomitic; streaks Anhydrite, as above.
450-480	Siltstone, orange, reddish orange; grades to silty Shale, rarely dolomitic, increased clear Anhydrite, inclusions; streaks Shale, red-orange,soft.
480-510	Shale, reddish orange, chunky, non-calcareous, rare Anhydrite inclusions; streaks Siltstone, as above.
510-535	Siltstone, reddish orange, slightly calcareous, argillaceous to shaley.

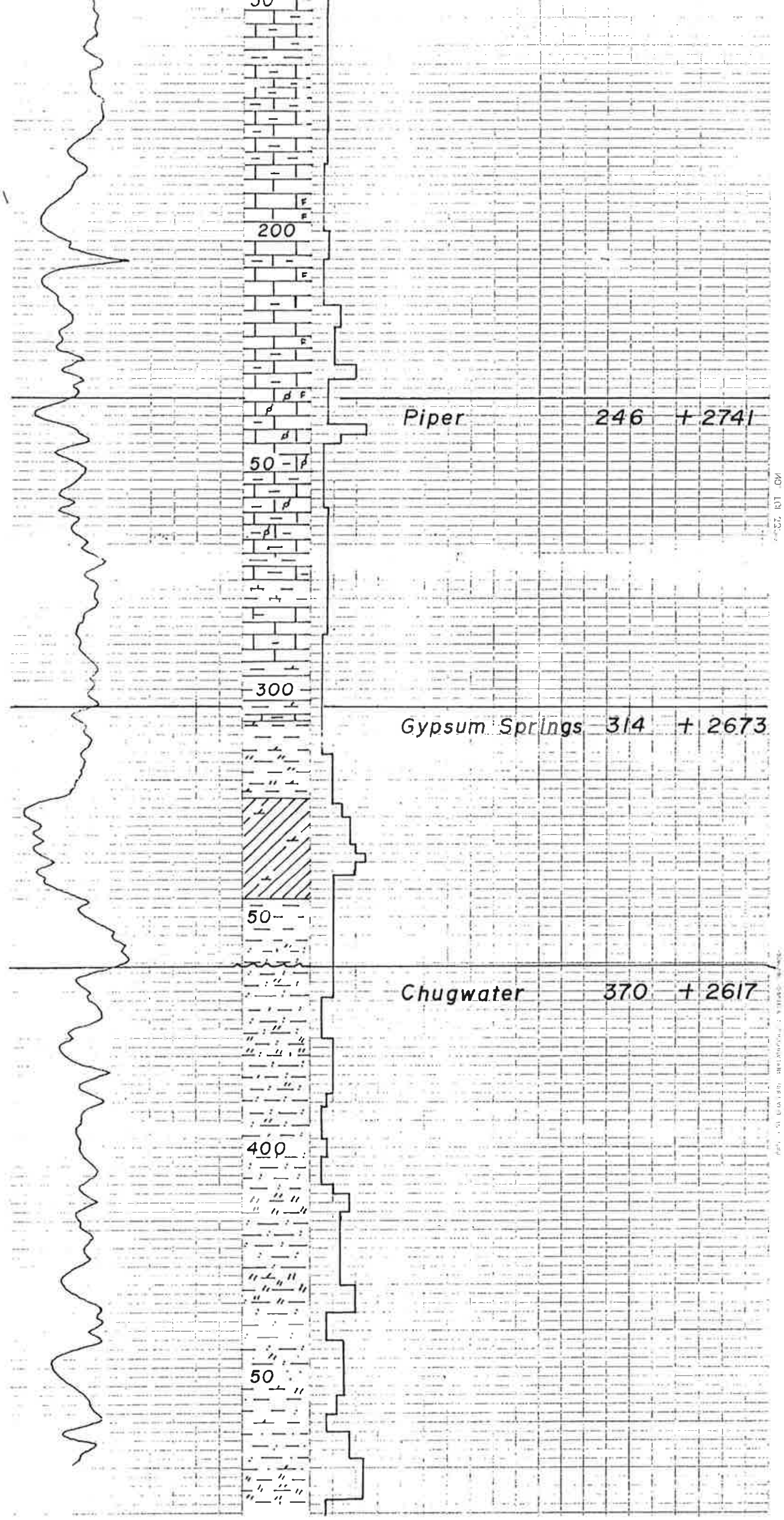
MONTANA DEPARTMENT FW&P

Bluewater Springs Trout Hatchery

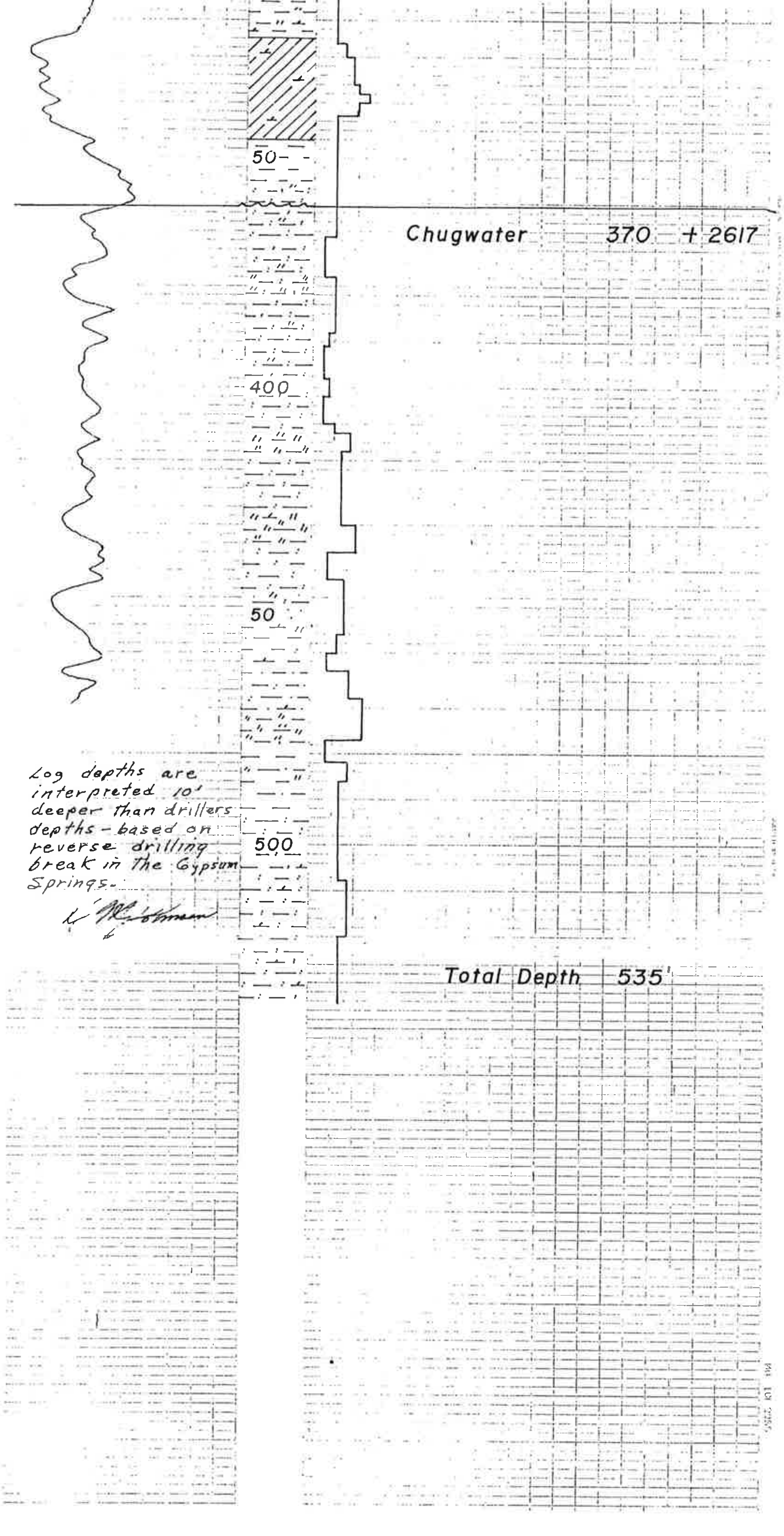
SW NW Sec. 9 - T6S - R23E

Carbon County, Montana





50
200
Piper 246 + 2741
50
300
Gypsum Springs 314 + 2673
50
Chugwater 370 + 2617
400
50


50
Chugwater 370 + 2617
400
50
500
Total Depth 535'
Log depths are interpreted 10' deeper than drillers depths - based on reverse drilling break in the Gypsum Springs.

A Hydrogeologic Evaluation of Long Term Recharge and Potential Interference of a Proposed Well for Robert Peccia and Associates

The Montana Department of Fish, Wildlife and Parks
Bluewater Springs Fish Hatchery
Near Bridger, Montana

Project BHEX-97-004
January 27, 1997

Braun Intertec Corporation

BRAUN ℠
INTERTEC

Braun Intertec Corporation
2611 Gabel Road
P.O. Box 80190
Billings, Montana 59108-0190
406-652-3930 Fax: 652-3944

Engineers and Scientists Serving the Built and Natural Environments℠

January 27, 1997

Project BHEX-97-004

Mr. Jeff Larson, PE
Project Engineer
Robert Peccia and Associates
P.O. Box 5653
Helena, Montana 59604

Dear Mr. Larson:

Re: Evaluation of Long Term Recharge and Potential Interference of a Proposed Water Well at the Bluewater Springs Fish Hatchery

Our evaluation of the long term recharge and potential interference of a proposed water well at the Bluewater Springs Fish Hatchery is completed in accordance with your request, and our proposal of May 22, 1996. We conducted a review of published and unpublished sources of data, identified the likely recharge area for the springs and wells in the Bluewater Springs area, and discussed the interconnection of aquifers and potential interference among wells and springs.

We believe that with proper well construction and management practices, additional groundwater can be developed on the west side of the Pryor Mountains. A test well completed in the Madison aquifer at the fish hatchery is needed to quantify the potential well yield and interference questions.

If you have any questions concerning the report, please contact me at (800) 786-3024. Braun Intertec has been pleased to provide hydrogeologic consulting services for this project.

Sincerely,

Thomas J. Osborne, CGWP
Principal Hydrogeologist

tjo:vcw

Enclosure:
Project Report

Table of Contents

A. Background

In conjunction with the rehabilitation of the Bluewater Springs Fish Hatchery near Bridger, Montana, the Montana Department of Fish, Wildlife and Parks (DFWP) is considering whether to construct one or more wells to supply water to the hatchery. As the engineer for this project, Robert Peccia and Associates requested that Braun Intertec conduct an additional hydrogeologic evaluation to support the DFWP's submittal of a Water Right Application. Specifically, the objective of our work was to evaluate the potential long term sustainable yield from the Madison aquifer, and comment on the potential for interference between proposed DFWP wells and a flowing well on the adjoining property.

B. Previous Studies

Previous work prepared by Braun Intertec related to this project include a hydrogeological report of February 15, 1996, and water supply well technical specifications and bid documents dated March 21 and April 15, 1996. The first of these reports discusses background data and synthesizes available information relevant to the hydrogeology of the Bluewater Springs area. Many other published and unpublished sources of data and reports were consulted during the preparation of this evaluation. These documents are referenced throughout and listed at the end of this report. None of the previous studies attempted to specifically address the objectives referenced above.

C. Geologic Structure and Groundwater Occurrence

The Bluewater Springs area lies immediately northwest of the Pryor Mountains, which consist of five tilted fault blocks with gently dipping westward facing slopes and steep escarpments on the eastern sides. The elevations of the summits of the Pryor Mountains range from 6,500 to 8,500 feet. U.S. Geological Survey Water Supply Paper 1779-J by Zimmerman (1964), which specifically evaluated the geology and water resources of the Bluewater Springs area, noted that the aquifers which supply groundwater to the Bluewater Springs area are recharged by precipitation over hundreds of square miles of outcrop. He noted that there is little surface water runoff from the Pryor Mountains, that the streams are generally ephemeral and that much of the precipitation on the mountains probably recharges the aquifers. He further noted that, inasmuch as these formations persist at depth throughout thousands of square miles and outcrop around other mountain ranges, the Pryor Mountains were not the sole area of recharge.

A wide range of bedrock units are exposed in the Pryor Mountains, ranging from Precambrian to Jurassic in age. There are two rock formations known as the Madison limestone aquifer and the Tensleep sandstone aquifer, which are exposed extensively in the Pryor Mountains and have been previously identified as potential sources of groundwater for both Bluewater Springs and other high capacity wells in the area. A detailed geologic map of the Billings 30x60-minute quadrangle has recently been prepared by Lopez (1996). A portion of this map with color coding of the Madison and Tensleep aquifers is presented in Figure 1.

Figure 1 also shows the presence of numerous faults and folds which are associated with the Pryor Mountain uplift and a system of en echelon faults known as the Nye-Bowler lineament. Note the high concentration of faults in the Bluewater Creek drainage. These faults are known to have displacements from a few feet to over 500 feet. Displacement is generally greatest in the area of maximum uplift within the Pryor Mountains, and diminishes in a westward direction. Faulting of the beds is important to groundwater flow because of the shattering of the rocks in the vicinity of the faults increases their permeability and provides conduits for water to discharge to high capacity springs and wells. The occurrence of the Madison and Tensleep aquifers at high elevations of the Pryor Mountains, and the consistent westward dip of these beds towards the Bluewater Springs area provides an ideal setting for the occurrence of artesian conditions in these aquifers once they are buried by overlying rocks west of the mountains.

It is believed that the overall structural geology on the west side of the Pryor Mountain uplift is responsible for the occurrence of Big Bluewater Springs and other high capacity artesian wells in the vicinity. A portion of the geologic structure map of the top of the Madison Group rocks published by Feltis (1984) is reproduced in Figure 2. Big Bluewater Springs and the 3,000-foot elevation contour line on top of the Madison Group rocks have been highlighted. As can be seen in Figure 2, the Madison Group rocks are extensively exposed in the Pryor Mountains, and the structure contours generally form a circular pattern around the mountains. Of particular note is that Big Bluewater Springs occurs on the nose of a structural arch on the northwest side of the uplift, at the point where numerous faults intersect the 3,000-foot contour of the Madison Group. This combination of geologic structure, faults, proximity to recharge in the Pryor Mountain uplift, and sufficient artesian pressure are believed to be the principal reasons for the specific location of Big Bluewater Springs and associated springs and wells.

The intersection of the Nye-Bowler lineament and associated fault swarms with the 3,000-foot elevation contour in Township 7 South, Range 24 East is quite pronounced. This area is known as "Red Dome," and was the subject of oil exploration drilling in the early part of this century. Although seeps of oil are known to exist in this area, exploration drilling never encountered economic oil deposits. However at least two old oil wells have produced large amounts of fresh water under artesian flow conditions over the past 70 or so years. It is believed that these wells derive their water from the Madison aquifer.

D. Groundwater Flow and Recharge Rates

The potentiometric surface of groundwater in the Madison aquifer has been mapped by Feltis (1980), and indicates that groundwater generally flows westward from the Pryor Mountain uplift towards the structural basin lying between the Pryor and Beartooth Mountains. Other studies (Downey and Dinwiddie, 1988) conducted by the USGS indicate that a portion of the groundwater flow in the Madison and Tensleep aquifers in the vicinity of the Pryor Mountains eventually becomes part of an extensive regional flow system in which groundwater moves from south central Montana, northeasterly towards the Williston Basin and eventually eastern North Dakota.

Groundwater in the Tensleep and Madison aquifers which does not move into the deep basin areas of Montana and the Dakotas, discharges locally to Big Bluewater Springs, many other springs in the area, the base flow of Bluewater Creek and the flowing well on the Ragland ranch, known as Ruckavina Well No. 2. With the exception of minor local snow melt and stormwater runoff, the entire flow of Bluewater Creek is supplied by discharge from the Tensleep and Madison aquifers. Zimmerman (1964) reported that a USGS stream gauging station on Bluewater Creek immediately downstream from the fish hatchery recorded average annual discharges of 25.9 cubic feet per second (ft^3/s) and 27.5 ft^3/s in 1960 and 1961, respectively. Based on hydrographs from these years, the estimated base flow of Bluewater Creek during periods free of local runoff events and high evapotranspiration rates is approximately 27 to 28 ft^3/s.

In a report on flow measurements of Big Bluewater Springs to the DFWP prepared by Roger Perkins (1992), a rough estimate was made of the recharge area potentially required to supply 27 ft^3/s of discharge on a sustained annual basis to Bluewater Creek. The report stated that if 18 inches of precipitation were received in the recharge area on an annual basis and that 15 percent of the total annual precipitation actually recharged the aquifers, a recharge area totaling 137 square miles would be required.

The Carbon County, Montana, Groundwater Inventory (1969) summarized annual groundwater level fluctuation information in alluvial aquifers of the county and estimated that approximately 10 percent of the total annual precipitation resulted in groundwater recharge to these aquifers. Other studies by the Montana Bureau of Mines and Geology of groundwater recharge to alluvial aquifers typically indicated that 5 to 15 percent of annual precipitation results in groundwater recharge.

It is generally believed, however, that greater percentages of the annual precipitation recharge exposed aquifers in mountainous areas where precipitation rates are higher. For example, USGS Professional Paper 1402-A (Downey and Dinwiddie, 1988) reports that the Wyoming State Engineer's office (1974) indicated an estimated recharge rate of 6.8 inches per year over 187,000 acres of Madison area outcrop in the Black Hills. This represents about 30 percent of the average annual precipitation of 22 inches (Peter, 1985). Major streams, such as the Tongue River in Wyoming and tributaries of the Judith River in Montana, are known to lose substantial portions, or in some cases, all of their flow to the Madison limestone as they cross outcrop areas. In the uplifted areas of the Pryor Mountains, it is believed that a reasonable estimate of the percentage of annual precipitation recharge to groundwater is in the range of 10 to 30 percent.

E. Recharge Area Identification

As a starting point in the process of evaluating the recharge area of the springs and wells in the Bluewater Springs area, the surface water basin of Bluewater Creek was delineated. This area, consisting of approximately 28 square miles, is shown on Figure 3. Most of the surface drainage basin is in the 14- to 15-inch precipitation zone (USDA, 1977), with only approximately one-third of the area covered by outcrop of the Tensleep Formation. The Madison Group rocks are not exposed at all. It is clear that the surface water drainage of

Bluewater Creek is inadequate to supply all but a tiny fraction of the observed base flow discharge.

Utilizing the detailed geologic map of Lopez (1996), along with other geologic references previously cited, and topographic and hydrologic information from the area, the recharge area for the Bluewater Springs area can be defined. This recharge area is shown as the multi-lobed elongated polygon defined by double lines in Figure 3. The large northwest and southeasterly lobes are shaped by the outcrop areas of the Madison and Tensleep aquifers in the west Pryor Mountain and Big Pryor Mountain areas, respectively. The crest of the structural arch in both lobes was defined as the most upgradient and highest elevation extent of the recharge area. The easternmost extent of the recharge area was defined by the Sage Creek surface water drainage, since all of its flow traverses Madison limestone or discharges into alluvium directly in contact with the Tensleep or Madison aquifers after it enters Bowler Flats. Most of the discharge of Sage Creek is believed to be lost as groundwater seepage to the bedrock or alluvium, excluding the portions lost to direct evapotranspiration or irrigation consumptive use. The area of alluvium in the west central area of the recharge area was included due to its likely hydraulic communication with the Tensleep and Madison aquifers, which it overlies. The alluvial area was demarcated by the major fault which bisects Bowler Flats from west to east and the contact with Triassic or Jurassic age rocks. The recharge zone identified in Figure 3 has a total area of approximately 190 square miles.

Utilizing the average annual precipitation map of Montana (USDA, 1977), an average area-weighted precipitation for the recharge area was calculated to be approximately 16.5 inches. If 15 percent of this average annual precipitation recharged the Tensleep and Madison aquifers, an average sustained groundwater yield of 34.6 ft^3/s would be produced. This is 23 to 28 percent more than the average base flow discharge of Bluewater Creek. Based on the data presented above, it is believed this is a reasonable and possibly conservative estimate of the average annual groundwater recharge to the Tensleep and Madison aquifers on the west side of the Pryor Mountains.

Based on synthesis of all available data, it is believed that Big Bluewater Springs represents the most significant natural groundwater discharge point for the Madison and Tensleep aquifers along the entire west side of the Pryor Mountains. This is because, prior to the installation of the flowing artesian wells at the Ragland ranch and in Red Dome, along with irrigation wells in Bowler Flats, there were no other large groundwater discharges along the west slope of the Pryors, other than those in the Bluewater Creek drainage. The presence of

350 to 400 acres of tufa deposits around Big Bluewater Spring and other springs in the vicinity, is very strong evidence that these springs have served as the principal groundwater discharge point for this extensive regional aquifer system for thousands of years. Tufa deposits are derived from groundwater containing excessive calcium carbonate in solution, which precipitates when groundwater reaches the surface and encounters the ambient atmosphere pressure.

F. Aquifer Interconnection

Based on the above interpretations, it is believed that the Tensleep and Madison aquifers are well interconnected in the vicinity of faults. The recharge area map previously discussed contains roughly 25 to 30 square miles of Tensleep aquifer outcrop. This area is entirely insufficient to supply the amount of discharge observed in the Bluewater Creek drainage. It is also generally true that the significant springs in the Bluewater Creek area are situated on or near faults, which permit vertical interconnection of the aquifers. It is quite possible that in the higher elevations of the Pryor Mountains, the Tensleep aquifer leaks water downward into the Madison aquifer.

This relationship was seen in the field in observations of a well as reported by Blair (1977). The well is located near the center of Section 19, Township 7 South, Range 24 East (See Figure 3, point A), and is depicted in cross-section in Figure 4. With a total depth of 1,400 feet, it penetrated both the Tensleep and upper half of the Madison aquifer. The static water level in the Tensleep aquifer was approximately 170 feet higher than that in the Madison aquifer. This indicates that hydraulic gradients were downward in this area, which is relatively close to the outcrop areas of the aquifer and higher in elevation than Bluewater Springs. At this location, the Tensleep and alluvial aquifers have the potential to recharge the Madison aquifer.

Further away from the outcrop area, it is likely that the reverse is probably true, where the head in the Madison aquifer is greater than that of the overlying Tensleep aquifer, and the vertical gradient is upward. The principal reason for this phenomenon is that the Madison aquifer is exposed at higher elevations in the Pryor Mountains than the Tensleep, and in the area of Bluewater Springs, it is buried deeper, resulting in greater artesian pressures.

The cross section depicted in Figure 4 illustrates that the Madison aquifer is apparently hydraulically connected to itself laterally across principal faults in the area. The well in Section 32 shown at point B in Figure 4 stared near the top of the Tensleep Formation, and penetrated most of the Madison Group to a total depth of 1,083 feet. It is located south of a major fault, which separates the west Pryor Mountain block from the Big Pryor Mountain block. The vertical displacement across the fault shown is approximately 600 vertical feet, yet the static water levels in the two wells are within approximately 2 feet of elevation, from the data reported by Blair (1977). The significance of this observation is that it supports the connection of the large Madison aquifer outcrop area exposed along the west flank of Big Pryor Mountain to the groundwater flow system of the Bluewater Springs area. The absence of other large springs along the west side of Big Pryor Mountain is additional evidence of the interconnection between the Big Pryor Mountain recharge area and the Bluewater Springs discharge area.

The Tensleep and Madison aquifers are separated by approximately the 150-foot thick Amsden Formation, which consists of beds of red and purple shale in the lower part, and soft and sandy limestone, along with beds of pink quartzite in the upper part. Generally, the Amdsen is too fine grained and well cemented to transmit water freely, except in cracks and fractures (Zimmerman, 1964). The Amsden can be considered a confining unit, except where fractures and faults allow water to be transmitted vertically between the underlying Madison and overlying Tensleep aquifers. It is believed that this situation generally exists in the uplift areas, which have been subject to extensive faulting, fracturing and weathering, and along significant fault systems away from the mountains, such as those in the Bluewater Creek drainage.

It is believed that the available water chemistry data indicates that these aquifers are interconnected in the Bluewater Springs area. The Ruckavina Well No. 2, which was sampled for inorganic water chemistry and described in our report of February 1996, has a dissolved solids concentration of approximately 1,200 milligrams per liter. According to information presented in USGS Professional Paper 1402-F on the geochemistry of water in aquifers of the northern great plains (Busby, et al, 1995), water derived from the Tensleep aquifer would be expected to have a dissolved concentration possibly twice this level, at this position in the groundwater flow system. The observed dissolved solids concentration in the Ruckavina No. 2 well is more typical of that expected from the Madison aquifer.

The mole ratio of magnesium to calcium in the water sample may also be indicative of the aquifer source. The Ruckavina Well No. 2 had a magnesium to calcium mole ratio of 0.25 (Braun Intertec, 1996). Magnesium to calcium mole ratios in the Tensleep aquifer would be expected to have values of 0.3 to 0.4, whereas the Madison aquifer would be expected to have mole ratios in the range of 0.25 to 0.35, closer to that observed in the Ruckavina Well No. 2.

G. Aquifer Yield and Drawdown

Although the available data discussed above indicates that the Tensleep and Madison aquifers are hydraulically connected in the area of Big Bluewater Springs, these data also indicate that the combined aquifer system is highly transmissive and porous, characteristics which tend to minimize the interference between producing wells, or between wells and springs. The available data and our understanding of the Madison aquifer in the areas away from significant faulting or fracturing suggests that it has a transmissivity in the range of 40,000 to 50,000 gallons per day per foot (gpd/ft). This is supported by an analysis of the Ruckavina Well No. 2 well by the Montana Department of Natural Resources and Conservation (DNRC)(Lemire, 1984), which calculated a transmissivity value of 45,000 gpd/ft from a specific capacity of 26 gpm/ft. In addition, an aquifer test on the Madison well shown in Figure 4 as Well B, located in Section 32 in the Bowler Flats (Blair, 1977), gave a value of 48,576 gpd/ft.

In areas associated with fracturing and faulting, transmissivity values may be as much as an order of magnitude greater. For example, an aquifer test conducted on Well A of Figure 4 (Blair, 1977) resulted in a transmissivity value of 208,400 gpd/ft. The evaluation of Big Bluewater Springs conducted by Perkins (1992), arrived at an estimate of transmissivity of between 300,000 to 400,000 gpd/ft. Values of transmissivity derived from aquifer tests on Madison wells in Rapid City, South Dakota, were also in the range of 100,000 to 400,000 gpd/ft (Greene, 1993), along the major axis of transmissivity. It is believed that this is a reasonable estimate for the Tensleep and Madison aquifer system at this location.

Based on preliminary evaluations, it is likely that there already has been a minor degree of interference between the Ruckavina Well No. 2 well and Big Bluewater Springs, similar to the magnitude described by Perkins (1992) and Braun Intertec (1996). At a distance of approximately one-half mile, the potential interference may be on the order of 10 to 20 feet of hydraulic head, given the current flow rates from the well and spring. In addition, it is likely that the flowing old oil wells or springs in the Red Dome area, approximately six miles south of Bluewater Springs, are tapping the same aquifer system and likely have an effect on the hydraulic head in the Madison aquifer. Apparently, to this date, the degree of interference has been insufficient to notice by the owners involved. Some degree of interference between wells located in the same aquifer always occurs. However, in most cases, appropriate well design and water management techniques are sufficient to satisfy the beneficial uses of the parties.

H. Future Groundwater Development

It is believed that additional development of groundwater from the Tensleep and Madison aquifers along the west flank of the Pryor uplift is possible without unmanageable interference problems. This is supported by the fact that groundwater development to date has not produced noticeable changes in flow or hydraulic head in the aquifers, and that regional studies of the Madison aquifer and other bedrock aquifers demonstrate that significant untapped quantities of groundwater enter the extensive flow systems that transmit groundwater into the deep basins of Montana and the Dakotas.

A study of the geohydrology of the Madison and associated aquifers in Montana and the Dakotas was conducted by the USGS and published in Professional Paper 1273-G (1984). This study conducted a computer simulation of groundwater flow through the Madison aquifer from recharge areas such as the Big Horn and Beartooth Mountains through Montana and the Dakotas. The study pointed out that, although a large part of the groundwater entering each aquifer is discharged within a short distance in springs and seeps along the flanks of the mountains, a fraction of the total recharge remains in the aquifer system and enters the regional flow system. The simulations in this study indicate that predevelopment recharge rates to the regional flow systems in the Big Horn and Beartooth mountain ranges to the Madison aquifer were on the order of 12 ft^3/s and 2 ft^3/s, respectively.

This study, along with the observed high degree of artesian pressure in the Tensleep and Madison aquifers, suggest that additional water can be made available to new high capacity wells that are properly designed and spaced, without unmanageable interference. It is very important that unregulated flowing wells are controlled or plugged so that valuable hydrostatic pressure and water is not wasted.

The potential groundwater production from the Tensleep or Madison aquifers and degree of interference can only be reliably evaluated with the installation of a appropriately designed test well. Our synthesis of all the available data regarding the Tensleep and Madison aquifers in this vicinity indicates there is an extensive recharge area, very high transmissivities in faulted zones and large ambient hydrostatic pressures, which suggest that with proper management, additional groundwater development can likely occur without adverse effects on existing users.

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J. Standard of Care

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession practicing in the same locality. No warranty is made or intended.

Figures

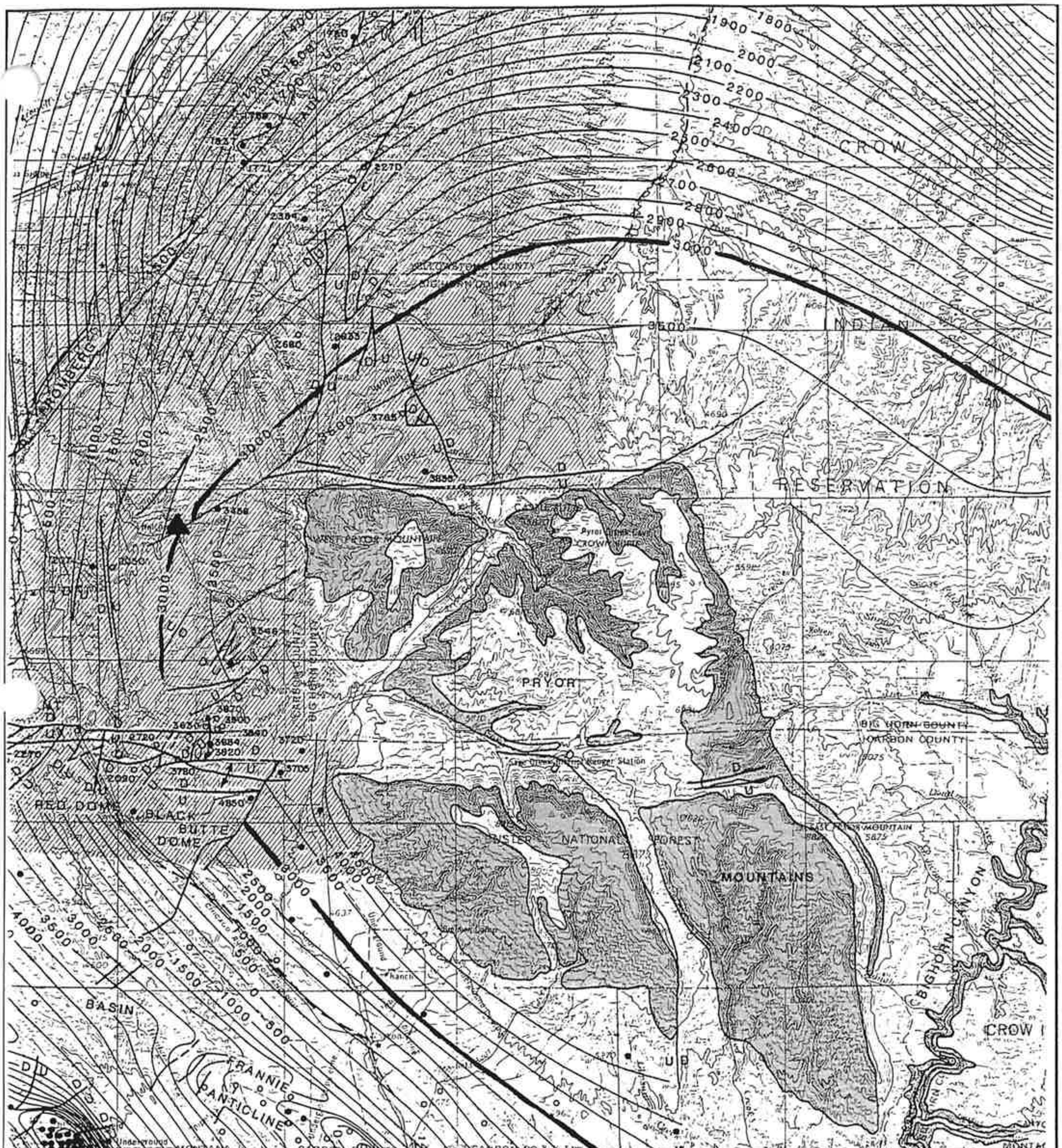
Legend

Tensleep Sandstone

Madison Group

Source: Lopez, 1996, Geology of the Billings 30 X 60 Minute Quadrangle, MBMG OFR 337.

BRAUN[SM] INTERTEC	Geologic Map of the Western Pryor Mountains and Vicinity, Taken from Lopez, 1996	BY	DATE	SHEET
		DRAWN BY: SKA	01/23/97	OF
		APP'D BY: TJO	01/23/97	
		JOB No. BHEX-97-004		
		DWG. No.	FIGURE # 1	
		SCALE 1:100,000		



Legend

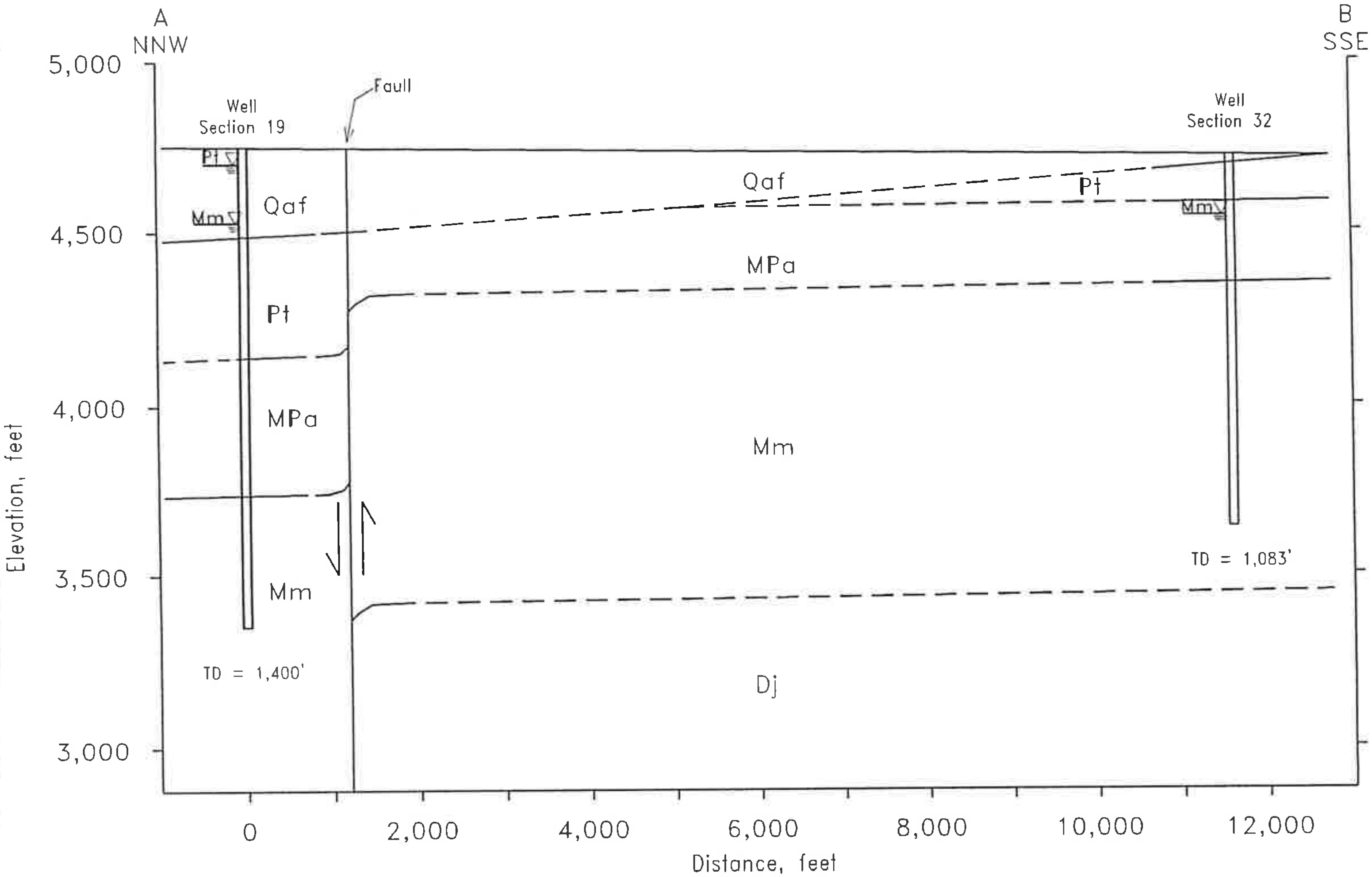
▲	Bluewater Springs	——	Elevation Contours, in Feet

Note: Taken form Feltis, 1984, MBMG Geologic Map 36.

BRAUN SM
INTERTEC

Map Showing Configuration of the
Top of the Madison Group
Pryor Mountain Area

INT	DATE	SHEET
DRAWN BY: SKA	01/24/97	
APP'D BY: TJO	01/24/97	OF
JOB No. BHEX-97-004		
DWG. No.	FIGURE # 2	
SCALE		



Key – Formation Age and Names

Qaf	Quaternary Alluvial Fan	Mm	Mississippian Madison
Pt	Pennsylvanian Tensleep	Dj	Devonian Jefferson
MPa	Mississippian – Pennsylvanian Amsden	∇	Static Water Level

Note: Information adapted from Blair, 1977; and Lopez, 1996.

INT	DATE	SHEET
DRAWN BY: SKA	01/22/97	
APP'D BY: TJO	01/22/97	OF
JOB No. BHEX-97-004		
DWG. No. BLUECROS	FIGURE #	4
SCALE 1 = 2,000		

Hydrologic Cross Section A–B
Across Bowler Flats
near Bridger, Montana
See Figure 3 for Location

BRAUN[SM]
INTERTEC

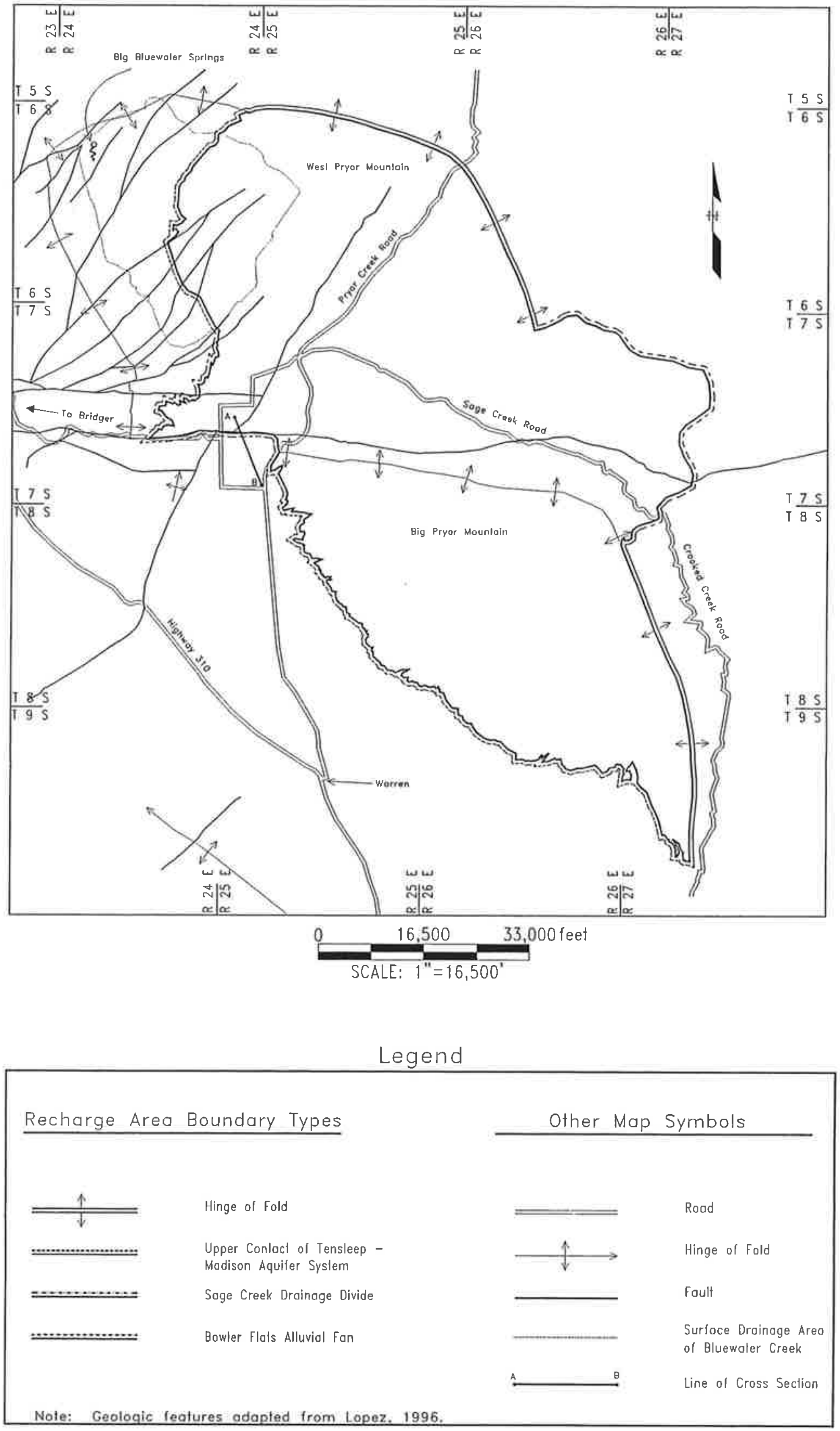


FIGURE #	INT	DATE
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	APP'D BY: TJO	01/22/97
	JOB No. BHEX-97-004	
	DWG.No. BLUEWAT	SHEET OF
	SCALE 1" = 16,500'	

Recharge Area of the Tensleep and Madison Aquifers Which Yields Groundwater Discharge to the Bluewater Springs Vicinity near Bridger, Montana

BRAUN[SM] INTERTEC

A Hydrogeologic Report for Robert Peccia & Associates

Hydrogeologic Evaluation for
Installation of a Well at the
Bluewater Springs Fish Hatchery
Bridger, Montana

Project BHEX-95-220
February 15, 1996

Braun Intertec Corporation

Table of Contents

A. Background

Braun Intertec has completed a hydrogeologic evaluation at the above-referenced site, in accordance with authorization of our September 28, 1995, work plan by Robert Peccia and Associates. These services are in support of a larger contract to provide engineering and environmental services to the Montana Department of Administration, Architecture and Engineering (A/E) Division and the Montana Department of Fish, Wildlife and Parks (MDFWP) for rehabilitation of the hatchery. The initial draft of the letter report was modified per comments from Roger Perkins, P.E., and those of the MDFWP and Peccia and Associates..

The objective of our services was to conduct a hydrogeologic evaluation prior to design and construction of a high-yield test well, which will supplement water supply needs of the hatchery. A secondary objective was to design a well with acceptable risk of impact to surrounding groundwater users.

This letter documents the results of Tasks 1 through 4 of our work plan, consisting of project scoping, hydrogeologic data collection and mapping, field survey, and overall hydrogeologic evaluation. Project data developed during the course of this evaluation are attached as appendices.

B. Site Hydrogeology

Hydrogeologic conditions in the Bluewater Springs area are complicated by deformed bedrock, faulting and a quaternary tufa deposit masking underlying bedrock.

Geologic materials considered in the Bluewater Springs area consist of the following bedrock units, in descending order from the surface.

- Quaternary, Tufa (Qt) - a calcium carbonate deposited by the numerous springs in the area.
- Late Cretaceous, Cloverly Formation (Kcl) - clay, shale, sandstone and black cherty conglomerate, found in area but not beneath this site.

- Jurassic, Morrison Formation (Jm) - clay, shale and sandstone, not beneath this site approximately 200 feet thick.

- Jurassic, Ellis Group

  -Swift and Rierdon Formations (Sundance) - shale, clay, limestone and sandstone, low permeability, at approximately 375 feet thick.

  -Piper Formation (gypsum springs) - massive gypsum beds, limestone and shale interbedded; source of calcium sulfates.

- Triassic, Chugwater Formation - (TRc) - red shale, red clay, red sandstone with interbedded gypsum at base and top. Not permeable enough to be an aquifer, approximately 175 feet thick.

- Permian, Embar Formation (Pp) - thin-bedded limestone; approximately 15 feet thick.

- Pennsylvanian

  -Tensleep Formation (Pt) - top 80 feet porous sandstone; good aquifer, approximately 105 feet thick.

  -Amsden Formation (Pa) - limestone, clay shale, conglomerate, chert, quartz filling cavernous top of Madison limestone, approximately 150 feet thick.

- Mississippian, Madison Limestone (Mm) - cavernous eroded top, limestone with quartz and chert. Good aquifer, approximately 1,000 feet thick.

A well to the Madison aquifer at the hatchery site will penetrate Tufa at the surface followed by the Jurassic Piper Formation and all subsequent formations to the Madison.

In general, these formations were deformed by the uplift of the Pryor mountains to the southeast. An anticline and syncline were formed in the Bluewater Springs area. These features are visible in the geologic map in Figure 1, Appendix A, and photographs in Appendix F. Following uplift, vertical faulting produced offset bedding and fractured rocks at great depth. The fracturing has provided a zone of enhanced permeability in which groundwater rises to the surface as springs. The spring waters take on a new chemistry as they pass through soluble minerals, such as calcium sulfate, which is later precipitated out at the surface as tufa.

Two cross sections were constructed that intersect near Big Bluewater Springs to evaluate subsurface aquifers and hydrogeologic characteristics. These cross sections are found in Appendix A, Figures 2 and 3. Note Section A-A' is perpendicular to three northeast-southwest trending faults in the Bluewater Springs area. These three faults are likely pathways for spring water and have been producing tufa deposits for a long time. Other deep vertical faulting in south central Montana suggest quaternary movements have occurred, and nearby faults such as the Nye-Bowler-Sage Creek fault zone, North Pryor fault, and the Fromberg fault zone are similar in structure, trend and age (Reheis, 1985).

The two main aquifers are the Tensleep and the Madison. The Tensleep Formation is 80 feet thick and is a sandstone deposit that has excellent pore space for conducting and storing groundwater. The top of this formation is at about 735 feet below Big Bluewater Springs.

The Madison Formation has been determined to be cavernous at the top, though breccia from overlying Amsden fills cavernous spaces. The faulted areas would likely contain open spaces dissolved away in part by groundwater. The top of the Madison is at about 1,010 feet below the Big Bluewater Springs. Depths of formations were determined from surface mapping, measured dips of rock formations, measured vertical offset along faults and from historical publications and well logs.

Vertical offset at the two faults bounding the Bluewater Springs Hatchery is about 25 feet, and a third fault, referred to in literature as the Bluewater fault, has an offset of about 50 to 150 feet near the hatchery.

The second cross section B-B' runs parallel to the center fault (nearest Big Bluewater Spring), and dissects several springs and Ruckavina Well No. 3. This section is along the axis of the anticline.

Confined groundwater flow in the Tensleep and Madison is "leaked" upward through the low permeable beds of the Amsden, Chugwater and Ellis Formations along faults and fractures. It is possible that where the water meets the Piper's gypsum and anhydrite beds that solution channels are formed, allowing flow laterally beneath the low permeable Ellis Formations (Swift and Rierdon) as may be the situation at Big Bluewater Springs.

C. Water Quality and Flow Evaluation

Measurements of water flow and water quality parameters were collected from selected springs and wells in the vicinity of the Bluewater Springs Fish Hatchery. The purposes of this effort were to establish benchmark conditions prior to installation of a test well, compare current measurements to any previously collected data, and yield additional information regarding the hydrogeology and hydrochemistry of potentially target aquifers. Field flow measurements were taken of the discharge from the Ruckavina No. 2 well, the Breakout Spring just east of that well, and Prewett Spring.

C.1. Water Quality Evaluation

C.1.1. Inorganic Water Chemistry. Water chemistry analysis for drinking water, primary and secondary parameters, was conducted on samples from Big Bluewater Spring and the Ruckavina Well No. 2. Drinking water quality analyses only were conducted of Tillet Spring, the Breakout Spring, Prewett Spring, and the Ragland Spring. Field water quality indicators of water temperature, specific conductance, pH and alkalinity were collected at all sites in the field. A summary of the water quality is included in Appendix B, Table 1, and the laboratory reports are attached in Appendix D.

The results of the laboratory analyses indicate that all of the sources sampled have a similar water chemistry, that being classified as a calcium sulfate type water. The water is very hard, with sulfate and total dissolved solids exceeding the maximum recommended for drinking water. Field water temperatures ranged from 11.6 to 14.5 degrees C. The pH ranged from 7.08 to 7.65 s.u., indicating near neutral to slightly alkaline conditions. Nitrate concentration was below 1 milligram per liter (mg/l) at all locations. Total metals concentrations from the Big Bluewater Spring and Ruckavina Well No. 2 were all below detectable levels. In addition, neither of these two samples exhibited gross alpha levels of radiation in excess of the laboratory detection limit of 1.0 picocuries per liter (pCi/l).

Water chemistry data collected in this study were compared to available data from previously published and unpublished sources. There exist previous reports of chemistry data from the

Madison group aquifer, however little to no definitive data were found specifically for the Tensleep aquifer. The general water chemistry of Big Bluewater and Tillet springs compares closely with previously published information on dissolved inorganic constituents from the Madison group aquifers based on a report published by R.D. Feltis (1980). Total dissolved solids (TDS) concentrations in the range of 2,000 to 3,000 parts per million are typical of wells and springs believed to derive water from the Madison formation in this region. Typically, sulfate comprises 75 percent or more of total dissolved anions present.

On the basis of TDS, water from the Ruckavina Well No. 2, Prewett Spring and Ragland Spring appear to be of considerably higher quality than the typical water chemistry. Water from these sources was lower in dissolved calcium, sulfate and total dissolved solids, compared to Big Bluewater and Tillet Springs. The water chemistry from Ruckavina Well No. 2 illustrates that cased wells will likely produce water with lower dissolved solids than nearby springs because water is produced through a casing rather than being exposed to soluble constituents in overlying rock. At this site in particular, calcium sulfate rocks, gypsum and anhydrite found in the Piper Formation are the likely source of these solutes. The lower TDS of Prewett spring and Ragland spring may be explained by the absence of certain rock beds rich in anhydride (calcium sulfate) and gypsum (hydrated calcium sulfate), owing to their having been removed by geologic weathering.

Comparison of water chemistry analyses collected from Big Bluewater Spring and Ruckavina Well No. 2 between this study and samples collected in March of 1960, illustrate that very little to no change has occurred in the chemistry of water derived from these sources (refer to Table 1).

Comparison between water chemistry data from Ruckavina Well No. 2 and the Breakout Spring illustrates the potential differences to be expected in waters derived from wells versus springs. According to well owner Richard Ragland, the Breakout Spring occurred when the Ruckavina well was temporarily shut in for repairs and the well casing was believed to have failed at depth. Shortly thereafter, a new spring appeared approximately 600 feet southeast of the well. The Breakout Spring has a calculated total dissolved solids of 2,100 mg/l compared to a measured total dissolved solids of 1,200 mg/l for the well. Calcium and sulfate content are also proportionately higher in the Breakout Spring compared to Ruckavina Well No. 2. If the postulated mechanism for the creation of Breakout Spring is correct, this water chemistry difference illustrates the very significant effect that percolation of groundwater through additional intervals of the Piper and Chugwater Formations can have on the water chemistry.

Although an accurate prediction of the water chemistry obtained from a drilled well at the Bluewater Springs Hatchery cannot be made, it is believed that such a well would produce water chemistry similar to that of Ruckavina Well No. 2, if cased to the Tensleep or Madison aquifer.

C.1.2 Corrosivity. An important characteristic of natural waters is the tendency to corrode metal or deposit minerals. The laboratory analyses of samples from Big Bluewater Spring and Ruckavina Well No. 2 included the Langlier Saturation Index (SI). A negative index indicates a tendency to dissolve calcium carbonate (CaCO3) and a positive index indicates a tendency to deposit CaCO3. Corrosion of metal pipes is retarded by a water with a slightly positive SI, which tends to deposit a thin coherent carbonate scale.

The laboratory SI of Big Bluewater Springs was -0.42, while that of the Ruckavina well was +0.24. Comparison of field pH to laboratory values indicate that the samples were not entirely stable in the day between these measurements. Field pH values were 7.17 and 7.65 compared to 6.2 and 7.1 for Big Bluewater Spring and the Ruckavina well respectively. When field calibration and conditions are acceptable, field pH values are generally considered more representative than laboratory measurement. SI calculations were re-run using field pH, temperature and alkalinity data. Re-calculated SI values were +0.37 and +0.61 for the spring and well respectively.

The results of the Ruckavina well are considered more representative of the groundwater to be derived from a drilled well at the hatchery. At this time there does not appear to be a potential corrosion problem from groundwater related to calcium carbonate under-saturation.

The possible presence of corrosive gasses such as carbon dioxide (CO_2) and hydrogen sulfide (H_2S) was not evaluated in this study or in any previous. It is recommended that the Ruckavina well be checked for the presence of these gasses prior to final well design.

C.2. Spring and Well Discharge Evaluation

During this study, flow measurements were taken in the field of Ruckavina Well No. 2, the Breakout Spring and Prewett Spring. The previous report on Bluewater Springs by Zimmerman, indicates that Big Bluewater Spring had a discharge of 2,080 gallons per minute (gpm) and Tillet Spring 426 gpm. However, no details were given as to the method and accuracy of the measurements. Previous measurements were summarized and additional measurements taken by Roger Perkins for the Department of Fish, Wildlife and Parks (Aquoneering, 1992). He indicated that the U.S. Geological Survey measured a flow of 4,300 gpm on December 1, 1977 (presumed to be combined flow of Big Bluewater and Tillet Springs). In his 1991 and 1992 studies, Perkins used several measurement methods to determine the discharge of the Big Bluewater and Tillet Springs. His calculations indicated that these springs flow a combined discharge of approximately 3,650 to 3,950 gpm.

The Ruckavina No. 2 Well was attributed a flow rate of 3,720 gpm under free flowing conditions in the 1960 report by Zimmerman. No references are given as to the source or method of measurement. A detailed flow measurement was taken of Ruckavina Well No. 2 during this study, in the outflow pipe from the well head to the stilling well. The results of this calculation indicate a total flow of 1,370 gpm. The Breakout Spring just southeast of Ruckavina Well No. 2 was measured at 309 gpm. Prewett Spring was measured in the outfall pipe from the reservoir just below the spring to the stream channel at 426 gpm. Velocity measurements were taken with a Marsh-McBirney magnetic-type flow meter. Details of the flow measurements and calculations are attached in Appendix E.

If the early measurements of Ruckavina Well No. 2 were reasonably accurate, the measurement of this study indicates that the flow from the well has declined substantially over time. Potential reasons for the decline of discharge are not known at this time.

D. Well Location Evaluation

Braun Intertec evaluated three alternate well locations on the Bluewater Springs Hatchery property. The three sites are depicted on Figure 4. Site No. 1 is located in the northeast corner of the property. It is easily accessible, posing no risks to sensitive vegetation. This site is slightly up gradient of Big Bluewater Spring, and closer to the Ruckavina well.

Site No. 2 is located about 140 feet south of the abandoned raceways and about 700 feet west of Big Bluewater Spring. It is situated nearly midway between the two faults traversing the property. No sensitive vegetation is anticipated. It is possible that the abandoned raceways could be used as mud pits during drilling, minimizing site disturbance. Due to the proximity of Bluewater Creek, runoff control will be needed.

Site No. 3 is in the southeast area of the property, about 400 feet south of Big Bluewater Springs, 50 feet inside the eastern property boundary. This location is about 1,000 feet to the fishery raceways and would require piping across wetlands and sensitive vegetation. Access to the site may require permission from the adjoining landowner. The accessibility to power and water is the poorest of the sites evaluated.

We selected Site No. 2 as the most favorable to maximize diversions from Big Bluewater Springs, minimize potential up gradient drawdown effects, and minimize site disturbance.

E. Well Yield and Interference

The discharge of water from a well or spring creates a cone of depression of the potentiometric surface around it. Under ideal conditions, the cone of depression assumes a circular shape gradually diminishing in all directions away from the well or spring. Although the Tensleep and Madison aquifers are separated, we assume that at Big Bluewater Springs, the two are interconnected to some extent. Bluewater and Tillet Springs create a cone of depression in the potentiometric surface of the Tensleep and possibly Madison aquifers, lowering the available head around the springs. Any reduction in available hydraulic head in the aquifer reduces the potential yield from a flowing well. Construction of a well at the Bluewater Springs Hatchery will create its own cone of depression, which will serve to diminish the available head, and consequently the discharge, of Big Bluewater and Tillet Springs. Nonetheless, the total amount of water derived from the springs plus a new well will be greater than that currently discharged only by the springs.

Theoretical calculations using the Theis equation of the potential drawdown created by Bluewater Springs were made using previously published estimates of aquifer properties found in the Zimmerman (1963) and Perkins (1992) reports. At a distance of 300 feet from Big Bluewater Springs, a reasonable estimate of drawdown might be on the order of 100 feet. Sensitivity analysis using a conservative and liberal set of assumptions yields a range of drawdown, at a distance of 300 feet, of 22 to 175 feet. Calculations are included in Appendix E.

The amount of available head in the Tensleep/Madison aquifers was estimated from a combination of information in the Perkins and Zimmerman reports. Zimmerman had estimated that a pressure head of 200 feet above land surface was present at the Ruckavina Well No. 2 when it was first drilled. However, Perkins pointed out that Zimmerman apparently neglected to account for head losses due to friction from water flowing up the cased well. He calculated the friction losses to be equivalent to from 250 to 275 feet of head. The true head in the Tensleep aquifer at Ruckavina Well No. 2 would be the sum of these two values or approximately 450 feet of pressure head above land surface. This estimate is supported by a potentiometric surface map of water in the Madison group prepared by Feltis (1980), which indicates that a few miles east of the Bluewater Springs site hydrostatic head is at 4,400 feet above sea level. The elevation of Bluewater Springs Fish Hatchery is approximately 4,000 feet. No data on the hydrostatic head in the Madison aquifer could be found in published or unpublished sources for this site. It is believed that the head in the Madison aquifer is likely somewhat greater than that in the Tensleep aquifer.

A well at the Bluewater Springs Fish Hatchery would have a theoretical total maximum pressure head of approximately 400 feet, with head subtracted due to interference from Big Bluewater and Tillet Springs and friction losses in the well bore when the well was flowing. If it is assumed that 100 feet of pressure head are lost to interference from the spring, and that 100 to 200 feet of available head would be given to friction losses, then from 100 to 200 feet of available head should remain to produce water flow from the well.

The amount of flow from the well under this scenario could be estimated utilizing previous estimates of the specific capacity of wells and springs that tap the Tensleep or Madison aquifers. Zimmerman calculated that the Ruckavina Well No. 2 had a specific capacity of 26 gallons per minute per foot of drawdown at the well (gpm/ft). Perkins conducted an experiment to test the specific capacity of Bluewater Spring and found specific capacities ranging from 133 to 200 gpm/ft. Using the more conservative number, discharge from a well at Bluewater Springs could produce in the vicinity of 2,000 to 3,000 gpm, however due to the many uncertainties which affect flowing wells, we believe an estimate of 1,000 gpm is safer.

Yields from a well at the Bluewater hatchery will be maximized if the well is located as far as possible from existing wells and springs and the well diameter is as large as is feasible. The larger diameter will minimize head losses due to friction in a flowing well. The actual yield of the well will depend on many specifics of well location, depth and details of well construction, as well as many unknown subsurface hydrogeologic conditions.

Another potential interference question arises in evaluating a proposed new artesian well at the hatchery with respect to the Ruckavina well and springs on the Ragland ranch property to the east. Perkins (1992) noted the potential for interference between the Ruckavina well and Big Bluewater Spring. He estimated that the Ruckavina well may have caused a reduction of 10 to 20 percent in the flow of the Big Bluewater Spring. A reliable quantitative estimate of potential interference is very difficult to make due to lack of site specific aquifer parameters. Some general observations can be made as follows:

- The proposed well is designed to obtain groundwater only from the Madison aquifer. The Ruckavina well is constructed only through the shallower Tensleep aquifer. Springs presumably also obtain water primarily from the shallower Tensleep aquifer.

- The proposed well location is generally down gradient (west) about 800 feet from Big Bluewater Spring. Standard hydrogeologic interpretations show that the capture zone of the new well will first and foremost impact yield from this spring and nearby Tillet Spring. The significant springs and well on the Ragland ranch are 4,000 to 5,000 feet or more up gradient from the proposed hatchery well location and are closer to the recharge area in the Pryor Mountains.

- The proposed new well is being drilled in an area between two faults mapped in this study. We anticipate enhanced permeability of the aquifers at this location and potentially less regional drawdown effect.

The depth and placement of the proposed well is designed to divert discharge from Big Bluewater and Tillett Springs. Although theoretically there is potential for interference with off-site wells and springs, it is our opinion that the above factors will mitigate the likelihood of experiencing actual problems that could not be addressed by coordination of management goals. Hydraulic head and discharge from the new well and other area wells and springs should be monitored to verify post-construction conditions.

F. Conclusions and Recommendations

Based on our review of available data and information, and the evaluations described above, Braun Intertec has reached the following conclusions.

1. Constructing a flowing artesian well to replace a portion of the spring water discharge from Big Bluewater and Tillet Springs is believed to be feasible at the site, as long as proper well construction techniques are utilized. Although the Tensleep aquifer is likely capable of supplying adequate well yield, the Madison aquifer is believed to be even more prolific. The depth to the top of the Madison aquifer is estimated to be 1,010 feet. A well in the Madison aquifer will minimize the potential for impacts to off site wells and springs, none of which are known to directly tap this aquifer. Locating the well down gradient (west) of Big Bluewater Spring will maximize the transfer of discharge from the spring to the well.

2. It is estimated that the Tensleep and Madison aquifers have approximately 400 feet of hydrostatic head above land surface at the site. The discharges of Bluewater Spring and Tillet Spring, along with Ruckavina Well No. 2 and other springs all serve to lower available head. However, it is believed that sufficient head remains in the Tensleep/Madison aquifers to supply a new flowing artesian well. The yield will depend upon well diameter, depth, location and construction details, but if optimally located and constructed, should flow at least 1,000 gpm. When flowing, the new well will somewhat reduce the discharge of Big Bluewater and Tillet Springs.

3. Although Zimmerman (1960) predicted that water chemistry from the Tensleep and Madison aquifers at the Bluewater Springs site would yield water of 700 mg/l and 1,500 mg/l respectively, we predict that total dissolved solids concentrations from a test well would be approximately 1,200 mg/l, similar to that of the Ruckavina Well No. 2. At this time, we have insufficient information to differentiate the dissolved solids concentrations and constituents between the two aquifers. Due to the extensive faulting at the site, waters from these two aquifers may already be mixing to some degree.

4. Given the history of gradual loss of yield and eventual failure of steel-cased wells into the Tensleep and Madison aquifers in this area, well drilling and construction must be of high caliber. Due to potential pressure differences, the well should not cross-connect the Madison and Tensleep aquifers to prevent intermixing and loss of yield. The well should be cased through all formations overlying the Madison aquifer.

Due to high hydrostatic pressures at depth and erosive surface formations, it is important that the well drilling contractor have blow out prevention capability and high capacity mud pumps and related equipment, along with appropriate experience to control the pressures and properly complete the well. The potential to encounter corrosive groundwater from these aquifers should be evaluated, with appropriate design considerations given to adequate well materials, grout and access for maintenance.

Based on the above evaluation and conclusions, Braun Intertec has the following recommendations.

1. Only drilling contractors with extensive experience in drilling deep wells under high hydrostatic head conditions should be considered for this project. These will most likely be oil field drilling contractors. Drillers should have adequate blow out prevention capability and adequate equipment, including mud pumps, drill stem test and grouting capability for the project.

2. The new well should be located as far as practicable from existing springs and should be of as large diameter as economically feasible. Well design should fully consider and balance pertinent hydraulic and economic constraints.

3. The well should be designed to protect surface formations, fully case and cement off the Tensleep formation, and extend casing to the top of the Madison aquifer. At lease 200 feet of borehole should penetrate the upper Madison formation and be left as an open hole completion.

4. Drill stem tests and geophysical logging should be conducted in the Tensleep and Madison aquifers during drilling to establish current hydrostatic pressure conditions and guide final well construction.

5. Well head construction should be adequate to allow shut in of the well, permit measurements of pressure and flow, and allow for replacement of the main valve and all well head appurtenances. Flow from the new well and Bluewater/Tillet Springs should be monitored indefinitely to evaluate potential long term changes in aquifer or well conditions.

G. References

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Reheis, M.C., 1985, *Evidence of Quaternary Tectonism in the Big Horn Basin, Wyoming and Montana,* Geology, v. 13, p. 364-367.

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H. Standard of Care

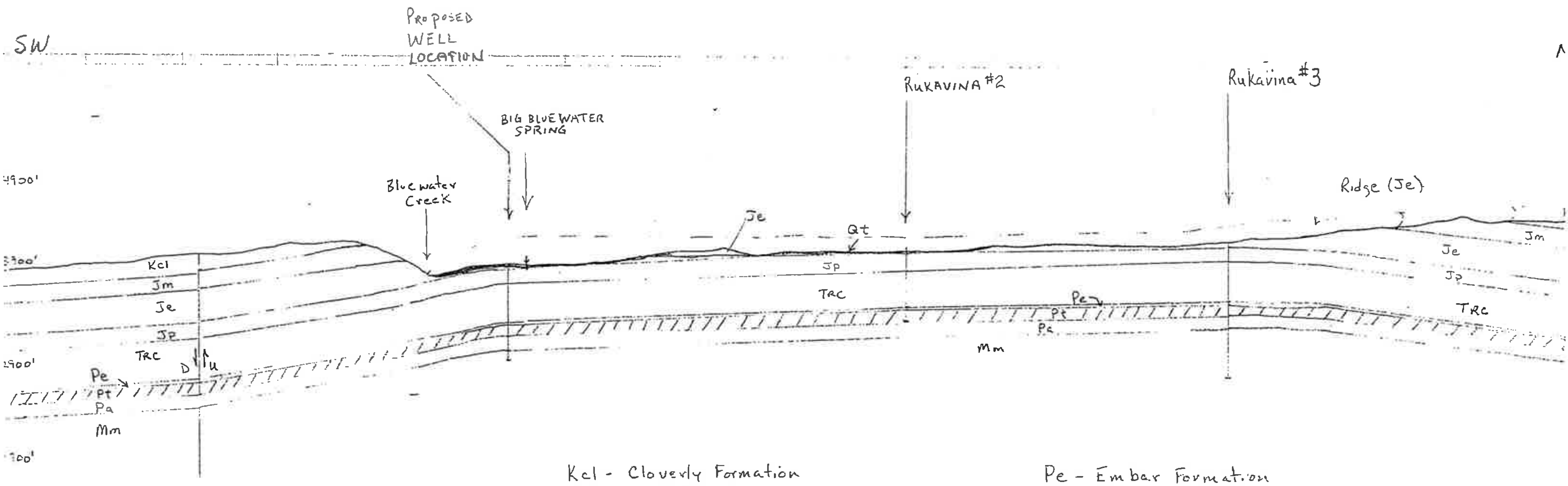
In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession practicing in the same locality. No warranty is made or intended.

Appendix A

BRAUN INTERTEC

GEOLOGIC MAP
BLUEWATER SPRINGS AREA
MONTANA

INT	DATE	SHEET
DRAWN BY: CEP	12/07/95	
APP'D BY: CEP	12/07/95	OF
JOB No. BHEX-95-220		
DWG. No.		FIGURE #
SCALE 1" = 2015'		1



SCALE

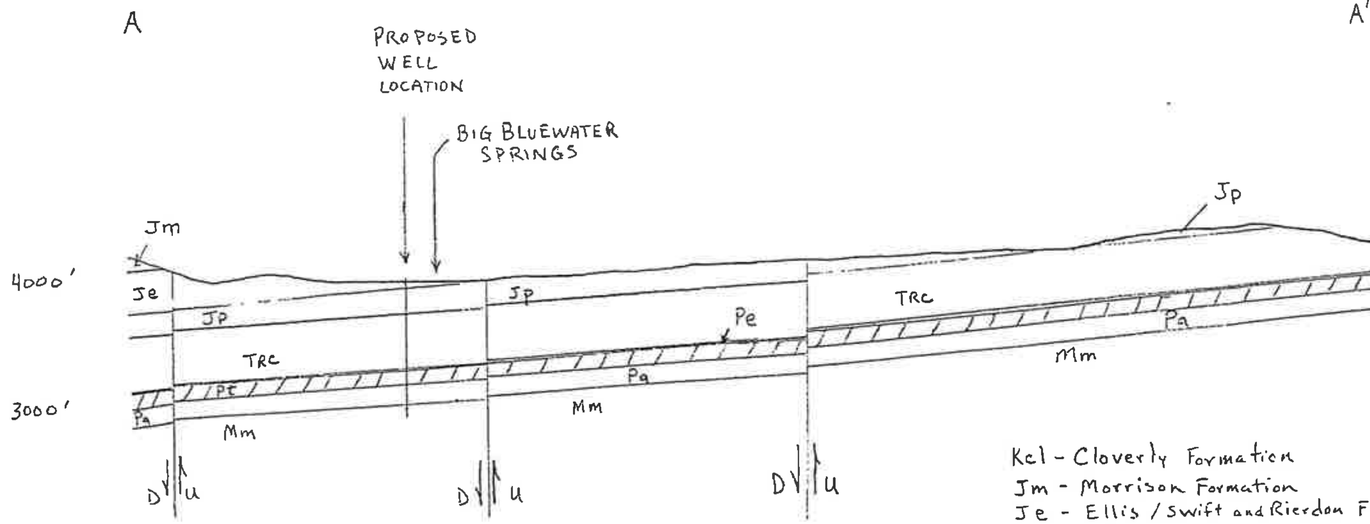
1" = 1000'

Kcl - Cloverly Formation
Jm - Morrison Formation
Je - Ellis / Swift and Rierdon Formation
Jp - Ellis / Piper Formation
TRC - Chugwater Formation

Pe - Embar Formation
Pt - Tensleep Formation
Pa - Amsden Formation
Mm - Madison Limestone

CROSS SECTION B - B'
BLUEWATER FISH HATCHERY

BRAUN INTERTEC	GEOLOGIC CROSS SECTION B-B' BLUEWATER SPRINGS AREA MONTANA	DRAWN BY: CEP 12/07/95 APP'D BY: CEP 12/07/95 FILE No: BHEX-95-220 DWG No: FIGURE # 3 SCALE 1" = 2015'



Kcl - Cloverly Formation
Jm - Morrison Formation
Je - Ellis / Swift and Rierdon Fm.
Jp - Ellis / Piper Formation
TRc - Chugwater Formation
Pe - Embar Formation
Pt - Ten Sleep Formation
Pa - Amsden Formation
Mm - Madison Limestone

SCALE
1" = 1000'

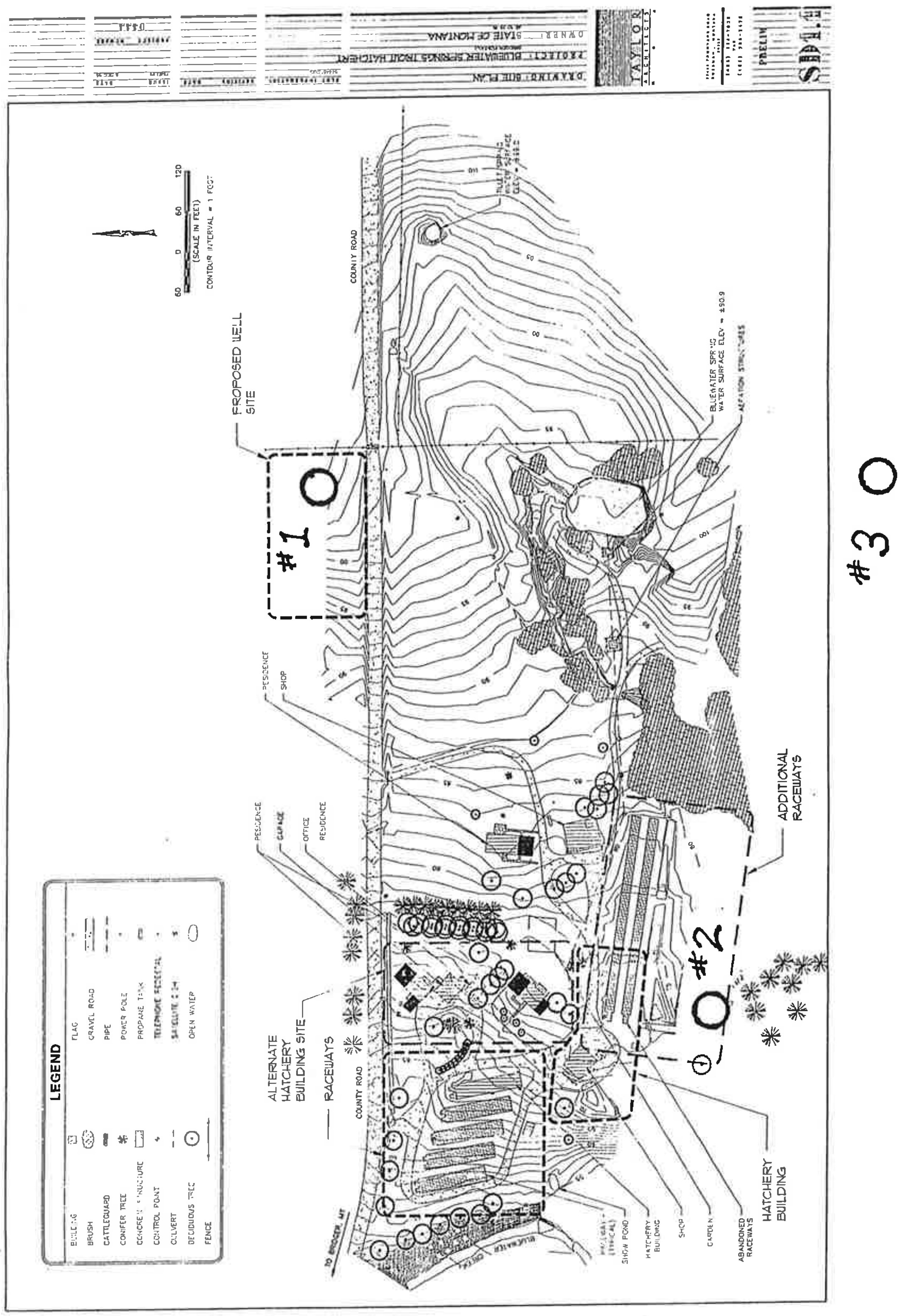
BRAUN INTERTEC	GEOLOGIC CROSS SECTION A-A' BLUEWATER SPRINGS AREA MONTANA	DRAWN BY CEP 12/07/95 APP'D BY CEP 12/07/95 JOB No. BHEX-95-220 DWG No. FIGURE # 2 SCALE 1" = 2015'

Knappen & Moulton 1930

Formations exposed in southern Yellowstone, western Big Horn, southern Stillwater, and northern Carbon Counties, Mont.

Period	Epoch	Group and formation		Thickness (feet) Extreme	Average	Character
Quaternary.	Recent and Pleistocene.					Gravel, sand, and clay.
Tertiary.	Pliocene (?).			0-5		Gravel and white or buff sand.
Tertiary (?).	Eocene (?).	Lance formation.		Not measured.		Dark andesitic continental sandstone and green, yellow, and black clay.
Cretaceous.	Upper Cretaceous.	Montana group.	Lennep sandstone.	120-310	170	Chiefly dark continental andesitic sandstone interbedded with yellow, green, and gray clay.
			Bearpaw shale.	250-425	400	Dark-gray marine clay and clay shale, with one andesitic sandstone.
			Judith River formation.	500-605	575	Interbedded dark continental andesitic sandstone and yellow, green, and gray clay.
			Claggett formation.	550-675	625	Dark-gray sandy marine clay with interbedded sandstones and massive mudstone. Parkman sandstone member, 280 to 310 feet thick, at top.
			Eagle sandstone.	200-250	210	Light-gray sandstone and shale, weathering buff to yellow. Prominent cliff former; carries coal.
			Telegraph Creek formation.	150-171	160	Yellow-buff sandy shale and sandstone.
		Colorado group.	Niobrara and Carlile shales.	1,060-1,230	1,100	Black fissile shale with minor sandy beds and many siderite concretions.
			Frontier formation.	305-420	410	Black fissile shale with thin sandstone (Peay sandstone member) below and massive yellow sandstone (Torchlight sandstone member) at top.
			Mowry shale.	180-325	225	Black fissile shale with numerous bentonite zones and some sandstone members.
				300-450	350	Black fissile shale, with rare bentonite beds.
			Thermopolis shale.	0-30	10	Black coarse stream-laid sandstone with much organic débris; "Muddy sand" of drillers.
						-Slight unconformity-
				270-290	280	Black fissile shale, with some rusty sandy beds in lower portion.
	Lower Cretaceous.	Cloverly formation.	-Gradational contact- Greybull sandstone member.	50-60	60	Rusty thin-bedded sandstone and sandy shale.
			-Gradational contact-	90-240	180	Bright variegated clay, volcanic ash, and shale.
				20-90	45	Black chert conglomerate and yellow sandstone.
		-Sharply channeled erosional unconformity-				
Cretaceous (?).	(?)	Morrison formation.		160-254	210	Yellow clay and shale and soft sandstone.
		-Slight erosional unconformity-				
Jurassic.	Upper Jurassic.	Sundance formation.		387-498	450	Varicolored shale, clay, and limestone below; olive-brown clay and sandstone above.
		-Slight erosional unconformity-				
Triassic.		Chugwater formation.		375-450	410	Red shale, red clay, and red fine-grained sandstone. Much interbedded gypsum including, near the top, one bed 15 to 40 feet thick.
		-Erosional unconformity of slight relief-				
Carboniferous.	Permian (?).	Embar (?) limestone.		10-15	12	Porous thin-bedded gray limestone.
		-Apparently conformable-				
	Pennsylvanian.	Tensleep sandstone.		40-105	70	Sandstone, medium to coarse grained, buff to cream-colored; eolian cross-bedding below; calcite cement above.
		-Marked erosional unconformity-				
		Amsden formation.		65-156	140	Red and purple shales, buff chalky limestone, and discontinuous thin pink quartzites.
		-Marked erosional unconformity-				
	Mississippian.	Madison limestone.		1,000±		Dark-blue or gray dense, fine-grained limestone with some quartzite and chert.
		-Erosional unconformity-				

Figure 4. Proposed Alternate Well Locations



Appendix B

Table 1. Water Quality Data for Bluewater Springs Area Montana[1]

Source	Date	Time	Field				Laboratory[2]													
			Water Temp. °C	Spec. Cond. uhmos/cm @ 25°C	pH s.u.	Alkalinity mg/l $CaCO_3$	K	Na	Ca	Mg	SO_4	Cl	CO_3	HCO_3	TDS	Spec. Cond. umhos/cm @ 25°C	pH s.u.	NO_3	Tot Fe	Gross Alpha pC/l
Big Bluewater Spring	11/14/95 03/31/60	1400	14.5	2,100	7.17	170	3 2	16 21	570 576	58 61	1,450 1,500	3 3.9	0	225 220	2,370 2,490	2,240 2,450	6.2	.18 .7		<1.0
Tillet Spring	11/14/95	1340	13.8	1,990	7.35	160	2	40	493	56	1,340	2	0	229	2,040	2,120	7.0	.20	.07	
Ruckavina Well No. 2	11/14/95 03/31/60	1650	13.2 ---	1,230 ---	7.65 ---	200 191	2 .8	3 1.7	282 262	45 39	683 620	2 .5	0	242 233	1,200	1,340 1,350	7.1 7.2	.24	0	<1.0
Breakout Spring	11/14/95	1555	13.6	1,982	7.08	---	2	11	538	56	1,380	3	0	230	2,100	2,160	7.0	.22	.10	
Prewett Spring	11/14/95	1445	12.4	1,554	7.37	200	1	5	359	75	990	3	0	236	1,550	1,710	7.2	.12	.10	
Ragland Spring	11/14/95	1700	11.6	771	754	---	2	7	137	51	353	2	0	229	664	944	7.3	.34	.03	

1 Refer to Appendix for complete laboratory results.
2 All units in milligrams per liter (mg/l) unless otherwise noted.

Appendix C

Well No.

Well Name Ajax Oil Co-
Rukavina #1 , 2

Twp. 6 S.
Rge. 24 E.

Structure
Blue Creek

Sec. 4

County
Carbon

Location
NW SE SE
990 N/S
990 W/E

State
Montana.

Surface Elevation and Formation
4190

Landowner
Rukavina API # 25-009-05260

Lessee
Ajax Oil Co

Drilling Company
Ajax Oil Co

Representative in Charge
Wm. G Dady , Geologist, Casper Wyo

Contractor or Drillers: Benedict, Huss, Ash

Date Location
9-27-49 App 11-3-49 FCP)

Date Spudded
9-27-49

10-7-49 Standing 141', 140' of 12½" c/w 50 sx (FCP) LOG IN FILE

12-2-49 Standing 141 MOCT (FCP)

12-9-49 SD 220, hole full of water (FCP)

12-23-49 Standing 539, (FCP)

12-30-49 Standing 610' (FCP)

1-6-50 Standing 588' ? (FCP)

1-27-50 Standing 693, 586' of 8-5/8 w/ 75 sx. Chugwater 240, SD for weather (FCP)

2-3-50 Flowing water in Tensleep (FCP)

Completed	Total Depth	Formation
2-15-50	787	Amsden?

Oil / Gas / Water
Abd as water well

Final Result
Abd
Left as water well

2-10-50 Drilling 760 (FCP)

2-15-50 More water, Standing 787 Amsden ? (FCP)

2-28-50 Abd as water well - tops later (HEW)

FROM SUNDRY NOTICE APP 4-8-50 FCP)
Well was abd as an oil possibility and comp as water well at the request of property owners and a copy of release from them is herewith submitted.
/s/ W.G.Dady

Sands:
635-685 Water (Tensleep)

Casing Record:
141' of 12½" w/ 50 sx
583' of 8-5/8" w/ 250 sx.

Completed as water well.

Formation tops (Per F.A.Woodard)

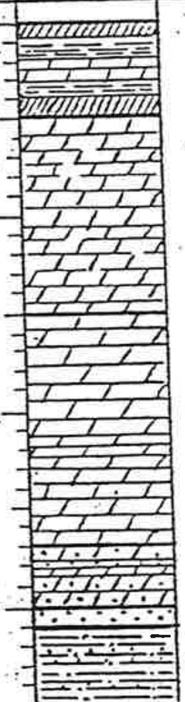
Chugwater	240
Embar	576
Tensleep	635
T.D.	789

NAME: RUKAVINA NO. 1 RAGLAND Flowing Well

Sec 4

STATE: MONTANA LOCATION: NW¼SE¼SE¼ T. 6 S. - R. 24E. DRILLED BY: AJAX OIL

COUNTY: CARBON ELEVATION: 4190 £ DATE: JANUARY 1950

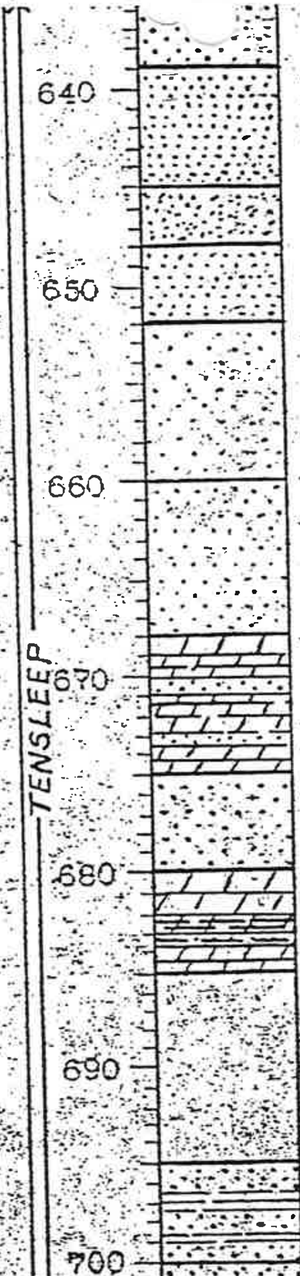
NOTES	DEPTH	LOG of HOLE	CLASSIFICATION
1. On January 13 the hole was cased and cemented-in at 583' and was filled with water to hold cement.	600		600' - 605' Anhydrite, dolomite and shale. Colors white, gray and red.
2. On January 19 the plug was drilled out. Water was left in the hole and drilling resumed.	610		605' - 615' Gray, cherty dolomite.
3. From 583' to 642' water was not bailed out. The water surface fluctuated between 20' and 50' from the top of the casing. There was no apparent inflow of water into the hole.	EMBAR 620		615' - 627' Gray dolomite. Some tar residues.
4. At 631' a small show of oil and gas-cut water came up with the bailer. There may have been some bubbling in the hole.	630		627' - 630' Light gray dolomite with sand grains. Some tar residue. 630' - 631' Gray sand. Oil and gas show. 631' - 635' Red shale and gray sand. Brown stains-black tar res.
5. At 642' the hole started to make			

... the hole started to make gas and oil-cut water which rose to the top of the casing. An vigorous effervescing spray rose 6" or more above the top of the water. Following bailings the water rose in the casing at a rate of about 20' in twenty minutes. The oil shows were slight and lasted about two hours. The gas continued to bubble for about 12 hours.

6. At 685' the hole started to make stagnant, black sulphur water which flowed about ¼" over the top of the casing. There was no appreciable increase in flow to 786'.

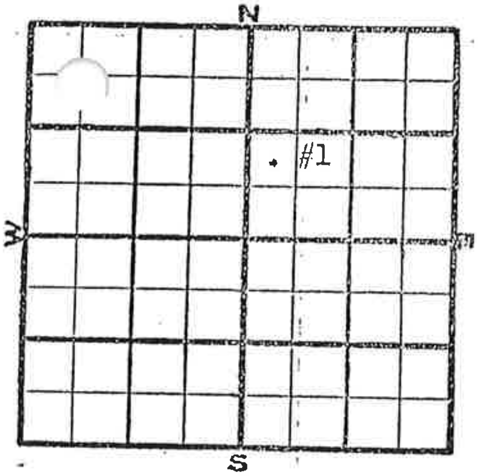
7. At 786' a heavy flow of water was encountered and was forced 15' or 20' above the top of the hole. Fragments of dolomite, which were heavily coated with tar residue, were carried to the surface.

RECEIVED
APR 6 1950
OIL CONSERVATION BOARD AND BOARD OF RAILROAD COMMISSIONERS
BILLINGS



635' - 639'	Red and gray sand. Sta[illegible] and saturated with brown oil.
639' - 645'	Pinkish-gray sand, medium-to fine-grained. Clusters of sand grains held together by oil.
645' - 648'	Fine, light-gray sand. Some asphaltic residue.
648' - 652'	Fine to medium-grained, brownish-gray sand. Sand clusters held together by asphaltic residue.
652' - 660'	Buff to brown sand. Stained with brown oil. Clusters of sand held together by asphaltic residue.
660' - 668'	Medium- to fine-grained, buff sand. Some tar residue. Clusters of sand grains held together by iron oxide.
668' - 675'	Gray dolomite and sand. Some tar residue.
675' - 680'	Fine to medium-grained, buff sand. Some tar residue.
680' - 685'	Gray dolomite and chert. Some green shale.
685' - 695'	No sample. (Probably sand).
695' - 700'	Fine-grained gray sand and green shale.

LOCATE WELL CORRECTLY



This Log to Be Rendered in Four Copies

Form 297—5M—2-51

Lease Rukavina 120

Board of Railroad Commissioners of the State of Montana

BOARD OF RAILROAD COMMISSIONERS OF THE STATE OF MONTANA

RECEIVED

Paul T. Smith, Chairman

Austin B. Middleton, Commissioner Leonard C. Young, Commissioner

OIL AND GAS WELL DIVISION

OIL CONSERVATION BOARD AND BOARD OF RAILROAD COMMISSIONERS BILLINGS

LOG OF OIL OR GAS WELL

Company Deep Rock Oil Corporation Address P.O. Box 1051, Tulsa, Oklahoma

Lessor or Tract Deep Rock Oil Corporation Field Wildcat State MONTANA

Well No. 1 Sec. 3 T. 6S R. 24E Meridian County Carbon

Location 2310 ft. { N. S. } of North Line and 2310 ft. { W. E. } East Line of Sec. 3 Elevation 4430' (Derrick floor relative to sea level)

The information given herewith is a complete and correct record of the well and all work done thereon so far as can be determined from all available records.

DRYHOLE

Signed James M. Moore

Title Office Manager

Date September 23, 1952

Address P.O. Box 1051, Tulsa, Oklahoma

The summary on this page is for the condition of the well at above date.

Commenced drilling September 27, 1951 Finished drilling December 6, 1951

Oil or Gas Sands or Zones (Denote Gas by G)		Important Water Sands	
NONE		NONE	
No. 1, from	to	No. 1, from	to
No. 2, from	to	No. 2, from	to
No. 3, from	to	No. 3, from	to
No. 4, from	to	No. 4, from	to
No. 5, from	to	No. 5, from	to

CASING RECORD

Size Casing	Weight per Foot	Threads Per Inch	Make	Amount	Kind of Shoe	Cut & Pulled From	Perforated From	Perforated To	Purpose
10 3/4"	32.75#	8 Rd.		188'		None	None		Surface Csg.
7"	20#	8 Rd.	J-55	918'		None	None		Intermediate

CASING OR TOOLS LOST OR SIDETRACKED None

From to Description

From to Description

From to Description

MUDDING AND CEMENTING RECORD

Ruckavina #3 (topo map)

Casing Size	Where Set	Number Sacks of Cement	Methods Used	Mud Gravity	Amount of Mud Used
10 3/4"	188'	200	HOWCO		
7"	918'	50	HOWCO		

PLUGS AND ADAPTERS - None

Heaving plug—Material .... Length .... Depth Set ....

Adapters—Material .... Size ....

SHOOTING RECORD - None

Size	Shell Used	Explosive Used	Quantity	Date	Depth Shot	Depth Cleaned Out

TOOLS USED

Rotary tools were used from 190' feet to 1457 feet, and from .... feet to .... feet

Cable tools were used from Surface feet to 190 feet, and from .... feet to .... feet

DATES

.... 19...... Put to producing Dryhole, 19......

The production for the first 24 hours was None barrels of fluid of which None % was oil; None % emulsion; None % water; and None % sediment.

If gas well, cu. ft. per 24 hours None Rock pressure, lbs. per sq. in. ....

Gallons gasoline per 1,000 cu. ft. of gas None

Plugged and Abandoned: 12-6-51

Clark Drilling Company - Drilling Cont.

EMPLOYEES

Seghetti, Driller. Biddy, Driller.

Ferranto, Driller. ...., Driller.

HISTORY OF OIL OR GAS WELL

It is of the greatest importance to have a complete history of the well. Please state in detail the dates of redrilling, together with the reasons for the work and its results. If there were any changes made in the casing, state fully, and if any casing was "side-tracked" or left in the well, give size and location. If the well has been dynamited, give date, size, position, and number of shots. If plug or bridges were put in to test for water, state kind of material used, position, and results of pumping or bailing.

FORMATION RECORD

From	To	Total Feet	Formation
0	10		Clay
10	20		Clay, Lime, Shells
20	30		Gravel
30	50		Lime, Rocks
50	60		Gravel, chalky
60	65		Shale, chalky
65	70		Shale & Gravel
70	150		Shale
150	190		Red clay

FORMATION RECORD

From	To	Total Feet	Formation
190	630		Shale & red beds
630	706		Phosphoria
706	719		Sand & Dolomite
719	724		Amsden
724	735		Sand & Lime
735	915		Amsden (red shale)
915	920		Madison (Hard lime)
920	1044		Amsden (Dolomite & lime)
1044	1048		Madison (Hard lime)
1048	1135		Lime
1135	1175		Lime Med. & Dolomite Med.
1175	1280		Lime
1280	1326		Madison (White & Medium)
1326	1382		Lime
1382	1457		Madison Lime (White)
1457			Total Depth

Board of Railroad Commissioners of the State of Montana
OCT 14 1952
RECEIVED 19

Appendix D

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1120 SOUTH 27TH STREET • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325
FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Tom Osborne
ADDRESS: Braun Intertec Corp.
P. O. Box 80190
Billings, MT 59108

LAB NO.: 95-68612
DATE: 12/04/95 cdt

WATER ANALYSIS

Ruckavina Well #2
Sampled 11/14/95 @ 1650
Submitted 11/15/95

Constituent	Drinking Water Quality Standard Max, mg/l	Found in Sample, mg/l (ppm)		Date Analyzed
Potassium		2		11/17/95
Sodium		3		11/17/95
Calcium		282		11/17/95
Magnesium		45		11/17/95
Sulfate	250	683		11/16/95
Chloride	250	2		11/16/95
Carbonate		0		11/16/95
Bicarbonate		242		11/16/95
Total Dissolved Solids @ 180°C	1500	1200		11/18/95
Total Hardness as $CaCO_3$		888		11/17/95
Total Alkalinity as $CaCO_3$		198		11/16/95
Specific Conductance @ 25°C		1340	µmhos/cm	11/15/95
pH	6.5-8.5	7.1	s.u.	11/15/95
Nitrate plus Nitrite as N	10	0.24		11/16/95
Total Iron	0.3	0		N/A
Corrosivity, Langlier Index @ 20°C		0.24		N/A
Fluoride		1.15		11/20/95
Color		0		11/16/95
Foaming Agents		<1		11/16/95
Odor		None		11/16/95
Gross Alpha		<1.0	pCi/l	11/30/95
Total Metals				
Arsenic	0.05	<0.005		11/16/95
Barium	1.0	<0.1		11/16/95
Cadmium	0.010	<0.001		11/16/95
Chromium	0.05	<0.01		11/16/95
Copper	1.3	<0.01		11/16/95
Iron	0.3	<0.03		11/16/95
Lead	0.05	<0.005		11/17/95
Manganese	0.05	<0.01		11/16/95
Mercury	0.002	<0.0002		11/22/95
Selenium	0.01	<0.005		11/17/95
Silver	0 05	<0.005		11/16/95
Zinc	5.0	<0.01		11/16/95

REMARKS: Very hard water. The sulfate exceeds the maximum recommended for drinking water.

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FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Tom Osborne
ADDRESS: Braun Intertec Corp.
P. O. Box 80190
Billings, MT 59108

LAB NO.: 95-68613
DATE: 12/04/95 cdt

WATER ANALYSIS

Tillot Spring
Sampled 11/14/95 @ 1325
Submitted 11/15/95

Constituent	Drinking Water Quality Standard Max, mg/l	Found in Sample, mg/l (ppm)		Date Analyzed
Potassium		2		11/17/95
Sodium		40		11/17/95
Calcium		493		11/17/95
Magnesium		56		11/17/95
Sulfate	250	1340		11/16/95
Chloride	250	2		11/16/95
Carbonate		0		11/16/95
Bicarbonate		229		11/16/95
Total Solids Calculated	1500	2040		N/A
Total Hardness as $CaCO_3$		1460		11/17/95
Total Alkalinity as $CaCO_3$		188		11/16/95
Specific Conductance @ 25°C		2120	μmhos/cm	11/15/95
pH	6.5-8.5	7.0	s.u.	11/15/95
Nitrate plus Nitrite as N	10	0.20		11/16/95
Total Iron	0.3	0.07		11/17/95

REMARKS: Very hard water. The total solids and sulfate exceed the maximum recommended for drining water.

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FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Tom Osborne
ADDRESS: Braun Intertec Corp.
P. O. Box 80190
Billings, MT 59108

LAB NO.: 95-68614
DATE: 12/04/95 cdt

WATER ANALYSIS

Prewitt Spring
Sampled 11/14/95 @ 1505
Submitted 11/15/95

Constituent	Drinking Water Quality Standard Max, mg/l	Found in Sample, mg/l (ppm)		Date Analyzed
Potassium		1		11/17/95
Sodium		5		11/17/95
Calcium		359		11/17/95
Magnesium		75		11/17/95
Sulfate	250	990		11/16/95
Chloride	250	3		11/16/95
Carbonate		0		11/16/95
Bicarbonate		236		11/16/95
Total Solids Calculated	1500	1550		N/A
Total Hardness as $CaCO_3$		1200		11/17/95
Total Alkalinity as $CaCO_3$		193		11/16/95
Specific Conductance @ 25°C		1710	μmhos/cm	11/15/95
pH	6.5-8.5	7.2	s.u.	11/15/95
Nitrate plus Nitrite as N	10	0.12		11/16/95
Total Iron	0.3	0.10		11/17/95

REMARKS: Very hard water. The total solids and sulfate exceed the maximum recommended for drining water.

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LABORATORY REPORT

TO: Tom Osborne
ADDRESS: Braun Intertec Corp.
P. O. Box 80190
Billings, MT 59108

LAB NO.: 95-68611
DATE: 12/04/95 cdt

WATER ANALYSIS

Big Blue Water Spring
Sampled 11/14/95 @ 1400
Submitted 11/15/95

Constituent	Drinking Water Quality Standard Max, mg/l	Found in Sample, mg/l (ppm)		Date Analyzed
Potassium		3		11/17/95
Sodium		16		11/17/95
Calcium		570		11/17/95
Magnesium		58		11/17/95
Sulfate	250	1450		11/16/95
Chloride	250	3		11/16/95
Carbonate		0		11/16/95
Bicarbonate		225		11/16/95
Total Dissolved Solids @ 180°C	1500	2370		11/18/95
Total Hardness as $CaCO_3$		1660		11/17/95
Total Alkalinity as $CaCO_3$		184		11/16/95
Specific Conductance @ 25°C		2240	μmhos/cm	11/15/95
pH	6.5-8.5	6.2	s.u.	11/15/95
Nitrate plus Nitrite as N	10	0.18		11/16/95
Corrosivity, Langlier Index @ 20°C		-0.42		N/A
Fluoride		1.22		11/20/95
Color		0		11/16/95
Foaming Agents		<1		11/16/95
Odor		None		11/16/95
Gross Alpha		<1.0	pCi/l	11/30/95
Total Metals				
Arsenic	0.05	<0.005		11/16/95
Barium	1.0	<0.1		11/16/95
Cadmium	0.010	<0.001		11/16/95
Chromium	0.05	<0.01		11/16/95
Copper	1.3	<0.01		11/16/95
Iron	0.3	<0.03		11/16/95
Lead	0.05	<0.005		11/17/95
Manganese	0.05	<0.01		11/16/95
Mercury	0.002	<0.0002		11/22/95
Selenium	0.01	<0.005		11/17/95
Silver	0.05	<0.005		11/16/95
Zinc	5.0	<0.01		11/16/95

REMARKS: Very hard water. The total solids and sulfate exceed the maximum recommended for drinking water. The pH is below the maximum recommended for drinking water.

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LABORATORY REPORT

TO: Tom Osborne
ADDRESS: Braun Intertec Corp.
P. O. Box 80190
Billings, MT 59108

LAB NO.: 95-68615
DATE: 12/04/95 cdt

WATER ANALYSIS

Raglan Spring
Sampled 11/14/95 @ 1735
Submitted 11/15/95

Constituent	Drinking Water Quality Standard Max, mg/l	Found in Sample, mg/l (ppm)		Date Analyzed
Potassium		2		11/17/95
Sodium		7		11/17/95
Calcium		137		11/17/95
Magnesium		51		11/17/95
Sulfate	250	353		11/17/95
Chloride	250	2		11/17/95
Carbonate		0		11/16/95
Bicarbonate		229		11/16/95
Total Solids Calculated	1500	664		N/A
Total Hardness as $CaCO_3$		551		11/17/95
Total Alkalinity as $CaCO_3$		187		11/16/95
Specific Conductance @ 25°C		944	μmhos/cm	11/15/95
pH	6.5-8.5	7.3	s.u.	11/15/95
Nitrate plus Nitrite as N	10	0.34		11/16/95
Total Iron	0.3	<0.03		11/17/95

REMARKS: Very hard water. The sulfate exceeds the maximum recommended for drining water.

ENERGY LABORATORIES, INC.
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FAX (406) 252-6069 • 1-800-735-4489

LABORATORY REPORT

TO: Tom Osborne
ADDRESS: Braun Intertec Corp.
P. O. Box 80190
Billings, MT 59108

LAB NO.: 95-68616
DATE: 12/04/95 cdt

WATER ANALYSIS

Breakout Spring
Sampled 11/14/95 @ 1620
Submitted 11/15/95

Constituent	Drinking Water Quality Standard Max, mg/l	Found in Sample, mg/l (ppm)		Date Analyzed
Potassium		2		11/17/95
Sodium		11		11/17/95
Calcium		538		11/17/95
Magnesium		56		11/17/95
Sulfate	250	1380		11/16/95
Chloride	250	3		11/16/95
Carbonate		0		11/16/95
Bicarbonate		230		11/16/95
Total Solids Calculated	1500	2100		N/A
Total Hardness as $CaCO_3$		1570		11/17/95
Total Alkalinity as $CaCO_3$		189		11/16/95
Specific Conductance @ 25°C		2160	µmhos/cm	11/15/95
pH	6.5-8.5	7.0	s.u.	11/15/95
Nitrate plus Nitrite as N	10	0.22		11/16/95
Total Iron	0.3	0.10		11/17/95

REMARKS: Very hard water. The total solids and sulfate exceed the maximum recommended for drining water.

Lab Nos. **95-68611-16**

QUALITY ASSURANCE DATA PACKAGE

This report includes the results of quality assurance tests performed with the sample analyses. They are performed to determine if the methodology is in control and to monitor the laboratory's ability to produce accurate and precise results.

	Duplicate Analysis -------mg/l (ppm)-------		Spiked Analysis, %	Blank Analysis,	-----Calibration Verification-----		
Constituent	Original	Duplicate	Recovery	mg/l (ppm)	Sample Analysis, mg/l (ppm)	Acceptance Range, mg/l (ppm)	Date Analyzed
Potassium	5	6	102	<1	19	18-22	11/17/95
Sodium	19	19	101	<1	49	45-55	11/17/95
Calcium	150	151	102	<1	50	45-55	11/17/95
Magnesium	258	260	100	<1	49	45-55	11/17/95
Sulfate	683	688	95	<1	322	286-350	11/16/95
Chloride	2	2	84	<1	76	69-85	11/16/95
Total Dissolved Solids @ 180°C	4680	4800	96	<1	N/A	N/A	11/18/95
Total Alkalinity as $CaCO_3$	42	43	103	3	103	85-115	11/16/95
Specific Conductance @ 25°C, µmhos/cm	302	301	N/A	1	N/A	N/A	11/15/95
pH, s.u.	6.4	6.3	N/A	N/A	N/A	N/A	11/15/95
Fluoride	1.15	1.15	97	<0.10	2.25	2.11-2.43	11/20/95
Nitrate plus Nitrite as N	0.18	0.18	93	<0.05	2.56	2.05-3.10	11/16/95
Total Metals							
Arsenic	<0.005	<0.005	104	<0.005	0.025	0.019-0.026	11/16/95
Barium	<0.1	<0.1	97	<0.1	1.0	0.9-1.2	11/16/95
Cadmium	<0.001	<0.001	104	<0.001	1.09	0.85-1.15	11/16/95
Chromium	<0.01	<0.01	103	<0.01	1.07	0.85-1.15	11/16/95
Copper	<0.01	<0.01	97	<0.01	0.98	0.85-1.15	11/16/95
Iron	<0.03	<0.03	103	<0.03	1.06	0.85-1.15	11/16/95
Lead	<0.005	<0.005	108	<0.005	0.014	0.013-0.017	11/17/95
Manganese	<0.01	<0.01	100	<0.01	1.04	0.85-1.15	11/16/95
Mercury	<0.0002	<0.0002	97	<0.0002	0.0016	0.0012-0.0016	11/22/95
Selenium	<0.005	<0.005	100	<0.005	0.099	0.081-0.128	11/17/95
Silver	<0.005	<0.005	101	<0.005	1.03	0.85-1.15	11/16/95
Zinc	<0.01	<0.01	106	<0.01	1.15	0.85-1.15	11/16/95

Lab No. 95-68611-16

Date: 11/15/95

Received by: Randa Hoelscher

Logged In by: Randa Hoeslcher

SAMPLE CONDITION QA/QC REPORT

This report provides information about the condition of the sample(s) and associated sample custody information on receipt at the laboratory.

Chain of Custody Form	Yes	Comments:
Completed & Signed	Yes	Comments:
Chain of Custody Seal	No	Comments:
Intact		Comments:
Signature Match Chain of Custody vs. Seal		Comments:
Samples Received Cold	Yes	Comments:
Samples Received Within Holding Time	Yes	Comments:
Samples Received in Proper Containers and Properly Preserved	Yes	Comments:

Client Notified About Sample Discrepancies

Who: ______ By: ______ Date/Time: ______

Additional Comments: ______

Method of Shipment Hand Delivered

ENERGY LA[illegible]RATORIES, INC.
P.O. Box 30916 1107 South Broadway
Billings, MT 59107
toll-free 800-735-4489
voice 406-252-6325
fax 406-252-6069

CHAIN OF CU[illegible]TODY RECORD

PLEASE PRINT OR TYPE ALL INFORMATION EXCEPT SIGNATURES

P.O. #

Project Name / Address: Braun Intertec, PO B 80190 Billings

Contact Name & Phone: Tom Osborne

Sampler's signature: Thomas J Osborne

Invoice to: Braun Intertec

Report to: "

DATE	TIME	composite	grab sample	SAMPLE I.D.	number of containers; Sample Type: A W S V U O (Air Water Soils/solids Vegetation Urine Other)	Analysis Requested: Domestic	Primary	Secondary	Gross Alpha				Comments, Special Instructions, etc.
11/14/95	1400		X	Big Blue Water Spring	4W	✓	✓	✓	✓				1 250 ml H_2SO_4 1 250 ml HNO_3
11/14/95	1650		X	Ruckavina Well #2	4W	✓	✓	✓	✓				1 250 ml H_2SO_4 1 250 ml HNO_3
11/14/95	1325		X	Tillot Spring	1W	✓							
11/14/95	1505		X	Prewit Spring	1W	✓							
11/14/95	1735		X	Raglan Spring	1W	✓							
11/14/95	1620		X	Breakout Spring	1W	✓							

	Relinquished (signature)	Date	Time	Received by: (signature)		Relinquished (signature)	Date	Time	Received by (signature):
1.	Thomas J Osborne	11/15/95	0830	Sandra K Ainsworth	3.				
2.					4.	Sandra K Ainsworth	11/15/95	12:50	Received for laboratory by (signature): Pam Fink 11/15/95 @ 1250

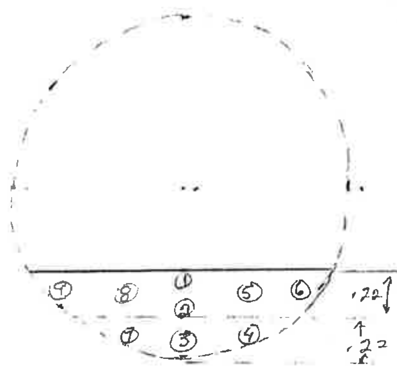
Appendix E

BRAUN[SM]
INTERTEC

Description: Ruckavina Well #2
Flow Calculation
Project No: Bhax 95-220
Date: 11-15-95 By: TJO

Discharge Pipe from Wellhead to Pump Station

i.d. = 1.75 ft r = 0.875
flow depth = 0.44 ft
Ratio 0.44/1.75 = 0.2514 = D/id



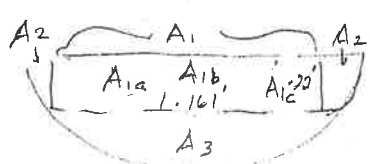
upper half of flow
Lower half of flow

From Merritt (1983)

D ft	D/id		PA/TA	TA ft^2	PA ft^2	
	.25	=	.196			
	.30	=	.252			
.44	.2514	=	.2117	2.405	0.5092	= Total flow area in pipe
	.10	=	.052			
	.15	=	.094			
	.1257	=	.0736	2.405	0.1770	= Area of lower 1/2 of flow
					0.3322	= Area of upper 1/2 of flow

Perrys Tab. 1-14a

D ft.	D/R	D/R	θ	D/Chord	Chord ft	Area ft^2
.22	.22/.875 =	.2514	83°	.189433	1.161	
.44	.44/.875 =	.5029	120°	.290	1.517	



$A_1 = 0.2554\ ft^2$ $A_{1a} = A_{1b} = A_{1c} = 0.085133$
$A_2 = .3322 - 0.2554 = 0.07678\ ft^2$
$A_3 = 0.1770$

FLOW CALCULATION

Sub Area	Area ft^2	Avg Vs ft/s	Qs ft^3/s
A1a	0.085133	6.68	.56869
A1b	0.085133	(6.36+6.53)/2	.54868
A1c	0.085133	5.80	.49377
A2	0.07678	(4.90+5.70)/2	.40693
A3	0.1770	(5.80+5.78+5.45)/3	1.03427
Total	.50918		3.05234 = 1,370 gpm

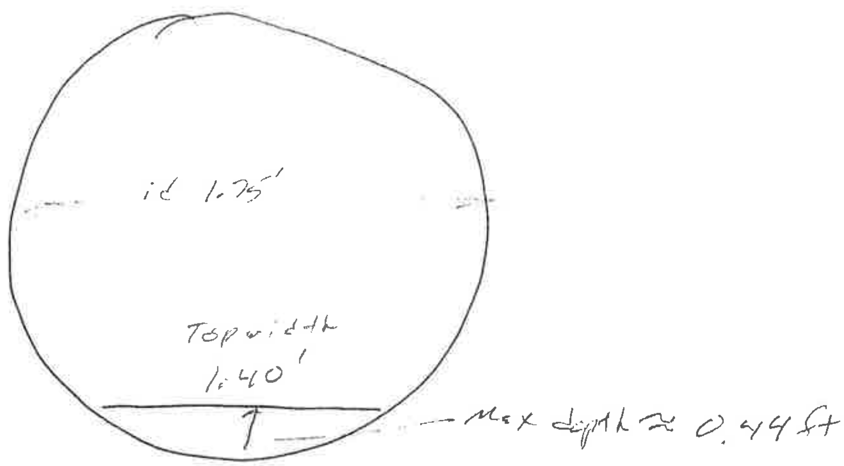
BRAUN INTERTEC

Description: Ragland Ruckavina Well 2

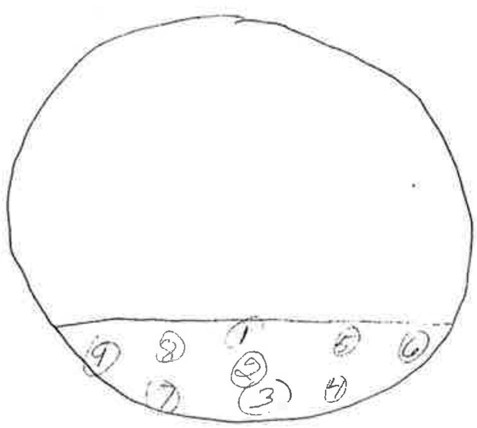
Project No:

Date: 11-14-95 By: TJD

Dimensions of pipe spilling to pumping well.



Velocity Measurements



1. 6.36 ft/s
2. 6.53
3. 5.80
4. 5.78
5. 5.80
6. 4.90
7. 5.95
8. 6.68
9. 5.70

Measured flow ~ 1 inch inside end of pipe.

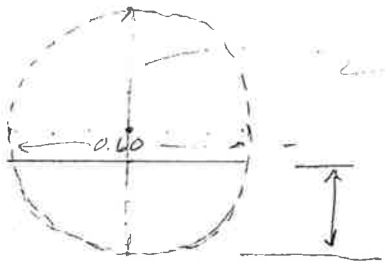
BRAUN INTERTEC

Description: Prewit Spring Flow Calculation

Project No: Bhex 95-220

Date: 11-15-95 By: TJD

8 inch o.d. Oilfield Pipe



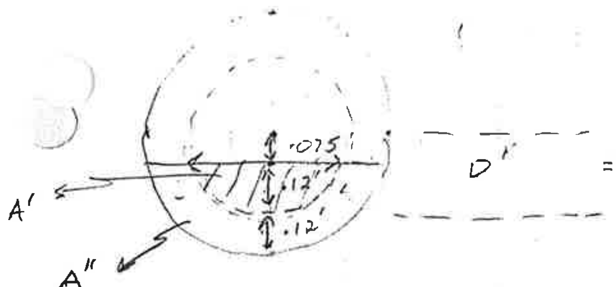
Measured i.d. = 0.63 ft, r = 0.315 ft

Measured top width

D = 0.24 ft

Perry's Table 5-19a

D ft	r	D/r	D/Chord	Chord, ft	A/r²	A, ft²
0.24	0.315	0.7619	0.39223	0.611	1.09912	0.10906



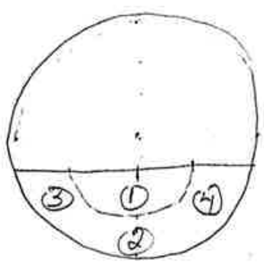
D' = 0.12' r' = 0.195'

D'	r'	D'/r'	D/Chord'	Chord, ft	A'/r²	A', ft²	by subtraction A" ft²
0.12	0.195	0.6154	.3333	0.360	0.82078	0.03122	0.07784

Flow Calculation

Sub Area	Area ft²	Avg v, ft/s	Qs ft³/s
A'	0.03122	9.2	0.2872
A"	0.07784	(9.0+8.2+8.3)/3	0.6616
Totals	0.10906		0.9488

= 426 gpm



Velocities ft/s

1 = 9.2
2. 9.0
3. 8.2
4. 8.3

BRAUN SM
INTERTEC

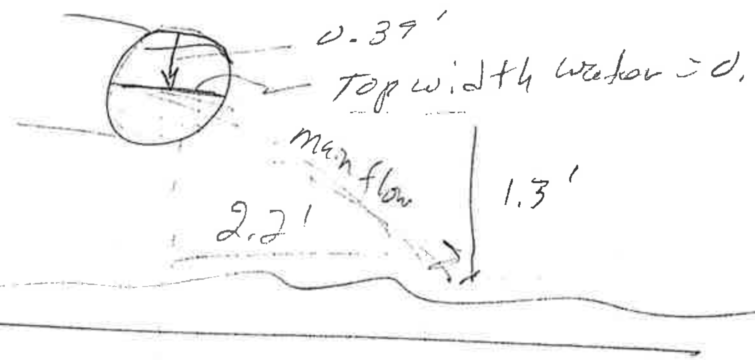
Description: ______________________

Project No: ______________________

Date: 11-14-95 By: [illegible]

Prewitt Spring @ culvert below dam

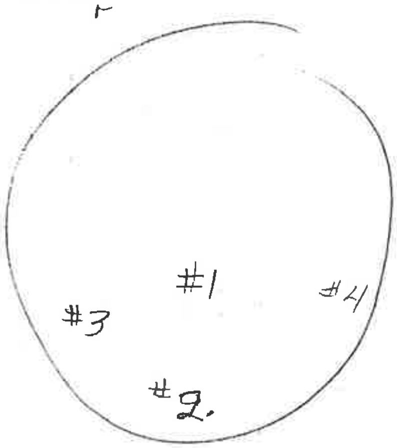
Dimensions 8" od pipe oilfield pipe
id = 0.65 ft.



Marsh-McBirney

#1 9.2 ft/sec
2 9.0
3 8.2
4 8.3

Field Temp 12.4 °C (orion)
SC = 1,380 umhos/cm @
Temp sc = 12.4 °C
F. pH = 7.37 stable
F. Alk -
phenolph. Alk = 0.
SO_4 < 10 drops to pink



9-275-F
Jan. 1956

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES DIVISION

DISCHARGE MEASUREMENT NOTES

Meas. No. ____________

Comp. by IJD

Checked by ____________

Sta. No. ____________

Breakout Spring, Raglan Ranch near Bluewater Spring

Date 11-14, 1995 Party IJD

Width 1.20 ft Area 0.352 ft² Vel. 1.96 ft/s G. H. — Disch. 0.69 ft³/s

Method ______ No. secs. ______ G. H. change ______ in ______ hrs. Susp. ______

Method coef. ______ Hor. angle coef. ______ Susp. coef. ______ Meter No. Marsh-McBirney

GAGE READINGS				
Time		Recorder	Inside	Outside
		none —		
Weighted M. G. H.				
G. H. correction				
Correct M. G. H.				

Date rated (R. Perkins owner) Used rating for rod ______ susp. Meter ______ ft. above bottom of wt. Tags checked ______

Spin before meas. ______ after ______

Meas. plots ______% diff. from ______ rating

Wading, cable, ice, boat, upstr., downstr., side bridge 70 feet, mile, above, below gage, and Little Bluewater Spring Pool

Check-bar, chain found ______

changed to ______ at ______

Correct ______

Levels obtained ______

Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section dirt hard bottom, earthen sides U shaped

Flow just above drop of couple inches Weather 55°F cldy.

Other ______ Air ______°F@ ______

Gage ______ Water ______°F@ ______

______ Record removed ______ Intake flushed ______

Observer ______

Control Several inch riffle just below section.

Remarks Measured just inside throat of converging section.

G. H. of zero flow ______ ft.

16—76791-1

Little Bluewater Spring River at— 11-14-95

Angle coefficient	Dist. from initial point	Width	Depth	Observation depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted for hor. angle or	Area	Discharge
Total Width 1.20											
ft.	0.05	.1	.19					1.90		.014	0.0361
	.15	.1	.30					1.97		.03	.0591
	.25	.1	.30					1.95		.03	.0585
	.35	.1	.31					1.82		.031	.0564
	.45	.1	.30					2.10		.03	.0630
	.55	.1	.30					1.75		.03	.0525
	.65	.1	.32					1.9		.032	.0608
	.75	.1	.30					2.14		.03	.0642
	.85	.1	.31					1.82		.031	.0564
	.95	.1	.30					2.4		.03	.0720
	1.05	.1	.31					2.4		.031	.0744
	1.15	.1	.28					1.28		.028	.0358
⊙											
	TOTAL									0.352	0.6892 ft³/s =

309.4 gpm

12-5-95

BLUEWATER SPRINGS THEORETICAL WELL INTERFERENCE CALCULATIONS 06-Dec-95

THEIS NON-EQUILIBRIUM EQUATION:

h0-h= (Q/4piT)*W(u)

u= (r^2*S)/4Tt

Parameters:		Units	SENSITIVITY ANALYSIS CONSERV.	LIBERAL
T	45000	gpd/ft	40000	300000
S	0.0001		0.0001	0.0001
Q	3800	gpm	4000	3600
	5472000	gpd	5760000	5184000
r	300	ft	300	300
t	100	days	365	90

Calculations:

u=	5.0E-07		1.5E-07	8.3E-08
W(u)=	13.93		15.19	15.72
h0-h=	134.80	ft	174.07	21.62

12-6-95

BLUEWATER SPRINGS THEORETICAL WELL INTERFERENCE CALCULATIONS 06-Dec-95

THEIS NON-EQUILIBRIUM EQUATION:

h0-h= (Q/4piT)*W(u)

u= (r^2*S)/4Tt

Parameters:		Units	SENSITIVITY ANALYSIS	
			CONSERV.	LIBERAL
T	45000	gpd/ft	40000	300000
S	0.0001		0.0001	0.0001
Q	3800	gpm	4000	3600
	5472000	gpd	5760000	5184000
r	600	ft	600	600
t	100	days	365	90

Calculations:

u=	2.0E-06		6.2E-07	3.3E-07
W(u)=	12.55		13.72	14.34
h0-h=	121.45	ft	157.22	19.72

BLUEWATER SPRINGS THEORETICAL WELL INTERFERENCE CALCULATIONS 07-Dec-95

THEIS NON-EQUILIBRIUM EQUATION:

h0-h= (Q/4piT)*W(u)

u= (r^2*S)/4Tt

Parameters:		Units	SENSITIVITY ANALYSIS	
			CONSERV.	LIBERAL
T	50000	gpd/ft	40000	300000
S	0.0001		0.0001	0.0001
Q	3800	gpm	4000	3600
	5472000	gpd	5760000	5184000
r	500	ft	200	500
t	120	days	120	120
Calculations:				
u=	1.0E-06		2.1E-07	1.7E-07
W(u)=	13.24		14.8	15.06
h0-h=	115.31	ft	169.60	20.71

Appendix F